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THESIS

A TASK ANALYSIS OF PIER SIDE SHIP-HANDLING FOR VIRTUAL ENVIRONMENT SHIP-HANDLING SIMULATOR SCENARIO DEVELOPMENT

by

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September 2000

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The approach taken was to use a Goals, Operators, Methods, Selection Rules (GOMS)-like model to represent the logical sequence of methods used by the conning officer. Critical Cue Inventories (CCI) were then developed to supplement the GOMS model by providing a list of the cues used along with detailed descriptions of why the cue was used and how it was visually or audibly identified. The accuracy of the pier side ship-handling task analysis was then validated by interviewing Surface Warfare Officers with several years of ship-handling experience by using the Critical Decision Method (CDM) knowledge elicitation process.

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A TASK ANALYSIS OF PIER SIDE SHIP-HANDLING FOR VIRTUAL ENVIRONMENT SHIP-HANDLING SIMULATOR SCENARIO DEVELOPMENT

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I. INTRODUCTION

A. MOTIVATION

Since the beginning of the Navy it has been commonly accepted that the true measure of a naval officer was his ability to "drive" a ship. Even today, this belief still holds true. For officers in the United States Navy's Surface Warfare community, ship handling or ship "driving" is a way of life. Often described as an art, a science and a skill, ship-handling is an individual's ability to apply science to develop the art of competently maneuvering a vessel safely and efficiently. Therefore to be a skilled shiphandler, one must master the science, understand the knowledge, and display the art, whenever and wherever required. [DNHM89]

Today, whether assigned to a large, nuclear aircraft carrier or a small frigate, surface warfare officers are continually required to demonstrate their ship handling skills. Therefore, one would assume that when a young surface warfare officer (SWO) walks onboard his first ship, his naval training should enable him to competently demonstrate the required ship handling skills. Unfortunately, this is not often the case. In recent years, many SWO's have been reporting to their first command with minimal ship handling experience. This problem was not due to the fact that these officers knew nothing about the "science" or fundamentals of ship-handling, but rather that they were not given the proper training to acquire the "art" of ship-handling. Despite the intensive training young surface warfare officers were receiving at their respective commissioning source and at their six month indoctrination course, they were not getting any "real" ship driving experience.

The Navy, plagued by numerous budgetary cutbacks, was being forced to train its surface warfare officers without the benefit of actual ships to train on. However, with the advances in technology and the development of cost-effective simulators, the surface warfare community has now turned its attention towards the consideration of supplementing traditional methods for training its young SWO's through the use of Virtual Environment (VE) trainers. Through the benefit of these simulators, young SWO's are now being able to gain invaluable ship driving experience prior to reporting to their first tour at sea.

In addition, the skill of ship-handling cannot be learned by solely reading books or observing someone else. Like so many other things in life, one cannot become proficient at something without practice. Hence, by training junior officers with these ship-handling simulators, the young ship drivers will be allowed to practice different types of ship-handling scenarios by themselves in a safe environment where they are allowed to make mistakes, try different methods, and begin to acquire the art of ship-handling or "seaman's eye."

B. OBJECTIVE

With specific goals provided by the Surface Warfare Officers School (SWOS), Naval Air Warfare Center, Training Systems Division (NAWCTSD) researchers have developed a "real time, high fidelity, networked virtual environment (VE) ship-handling simulator." [TNNY99] This simulator serves as a prototype for the Conning Officer Virtual Environment (COVE) system that is currently being commercially developed for the purpose of training ship-handling to surface warfare officers. The protoype simulator currently has the ability to replicate an Underway Replenishment (UNREP) scenario in which officers practice conning alongside evolutions. In addition, the researchers have also begun to implement other ship-handling scenarios, including pier side ship-handling and amphibious operations.

The objective of this thesis is to provide a thorough task analysis of pier side ship handling that will support further development of both the prototype and COVE simulator's pier work scenarios. A secondary objective is to provide an inventory of perceptual cues that are extensively used during pier side evolutions.

C. APPROACH

This thesis format follows that developed by Steve Norris. [NORR98] It contains a cognitive task analysis of a conning officer during two specific pier side evolutions: these are getting a ship underway from a pier and mooring a ship to a pier. The task analysis will be using the previously used GOMS notation method to present the two tasks of the conning officer. Additionally, the thesis will also present a perceptual cue inventory that represents items that cannot be successfully annotated on a GOMS model.

D. THESIS QUESTIONS

The following questions are addressed in this thesis:

- *What specific tasks are required of a conning officer while getting a ship underway from a pier?*
- *What specific tasks are required of a conning officer while mooring a ship to a pier?*
- *What are the perceptual cues used during pier side ship handling?*

- *Is the GOMS representation suitable for incorporating the perceptual cues?*

E. SUMMARY OF CHAPTERS

The remainder of this thesis is broken down into the following chapters:

- Chapter II provides a detailed review of the current training methods of surface warfare officers. It will also discuss the current state of maritime simulators as well as the research that is being done in support of the COVE project.

- Chapter III discusses the purpose and methodology of conducting a task analysis. Additionally, it will examine in detail the GOMS model, including its advantages and disadvantages.

- Chapter IV will review the pier side ship handling task and provide basic ship handling fundamentals. In addition, it will review the standard commands used by a conning officer during the task, as well as the emergencies he may encounter.

- Chapter V provides the task analysis including supporting narration. Additionally, it includes the perceptual cue inventory.

- Chapter VI discusses the results of the validation process of the model.

- Chapter VII presents a final discussion of the results of this thesis and describes areas requiring further research.

II. BACKGROUND

A. DEVELOPMENT OF A SHIP DRIVER

Once selected into the surface warfare community and before reporting to his or her first ship, a new surface warfare officer (SWO) must attend a six-month indoctrination class, known as the Division Officer Course. This course, held at the Surface Warfare Officers School (SWOS) in Newport, RI, provides newly commissioned naval officers, selected into the surface warfare community, with the necessary information and skills to be successful in their first tour as division officers afloat. Ensigns who graduate from the United States Naval Academy receive extensive training through the academy's fleet of Yard Patrol (YP) craft and report to SWOS with comprehensive ship-handling skills. Unfortunately, the majority of newly commissioned Ensigns come from other commissioning sources, such as the Naval Reserve Officer Training Corps (NROTC), and receive minimal ship-handling experience. Until the early 1990's, SWOS was also able to utilize YP's in teaching ship handling during the Division Officer Course. However, due to the age of the YPs and lack of funds to replace them, these assets are now unavailable. [NORR98] Thus, for junior officers coming from commissioning sources other than the Naval Academy, SWOS represents their first step in acquiring the basic fundamentals on ship handling. Therefore, many SWO's are now forced to master the "art" of ship-handling through on the job training exclusively.

The young SWO begins on the job training immediately as he walks on board his first ship. Realizing that the learning curve for ship-handling is very steep, many ships' watch bill coordinators, who are responsible for assigning personnel to specific watch sections, quickly put new officers on the bridge so that they can begin standing watches under instruction. The purpose of this practice is to allow the junior officer to begin to learn the traits of bridge watch standing and the basic fundamentals of ship-handling by observing the actions of the more experienced ship drivers.

A watch section consists of a team of crew members who, together, perform a required job or function onboard the navy vessel, such as the watch section that is responsible for safely driving the ship is the bridge watch team. A bridge watch team is usually made up of two officers (an officer of the deck and a conning officer) and five enlisted personnel (the Boatswain Mate of the Watch, the quartermaster, the Helmsman, the Leehelmsman, and the status board keeper). However, on larger naval ships, such as aircraft carriers, the officer watch stations on the bridge also include positions for a radar watch officer and communications watch officer. The Officer of the Deck (OOD), usually the most experienced ship-handler in that watch section, is in charge of the entire watch section. He is also responsible for the safety of the entire ship and its crew during his four hour watch. The Conning Officer is responsible for driving the ship. He is the one who gives all of the verbal orders to the Helmsman and Leehelmsman, who are responsible for properly executing the rudder and engine orders. Depending on the size of the ship's crew and the number of personnel qualified to stand a particular watch station, a ship will have anywhere from two to six watch sections that will be on watch for at least four hours at a time. Additionally, the watch bill coordinator will shuffle personnel between the watch sections in order to give all of the team members a chance to work with different watch standers.

As junior officers begin to stand watches on the bridge, they not only learn from observation, but they also gain invaluable experience as they begin to conn the ship. Most often, the new SWO's will be assigned to the watch team as a conning officer and be paired with a very experienced officer of the deck that will act as their teacher on the bridge. During critical evolutions, such as underway replenishments and pier side ship-handling, the young conning officers are also mentored by the commanding officer. Depending on their leadership traits, the commanding officer will offer advice and constructive criticism on the junior officer's performance. Only when the young SWO has gained the confidence of the commanding officer as a competent ship driver will he ever be considered for promotion to the position of OOD. Depending on the ship's underway schedule, the process of becoming a qualified OOD can, unfortunately, take anywhere from 8 to 18 months. Once a SWO has attained the status of being a qualified OOD underway, he or she continues to hone his or her ship-handling skills by standing hundreds of hours on the bridge.

Although this way of training eventually produces competent ship drivers, it places the young officer in a harsh learning environment. Most junior officers are so nervous and inexperienced when they conn a ship for the first time that they usually end up being a "parrot" where all they do is repeat orders given by the OOD or commanding officer. Or they get frustrated because they don't fully understand the fundamentals of ship-handling and therefore make numerous mistakes. Before a naval aviator reports to his first squadron, he spends hundreds of hours flying in a jet or simulator to acquire the skill needed to be a proficient pilot. Why should it be any different for a SWO?

B. CURRENT TRAINING OPTIONS

Recognizing the fact that new SWO's were not receiving any ship-handling experience prior to reporting to their first command, the Surface Warfare community realized that it was imperative that they provide an alternate method of teaching ship-handling. Therefore, following in the Naval Aviation community's footsteps, the Surface Warfare community began to develop ship-handling training through the use of virtual environment simulators. Currently, new surface warfare officers are taught the basics in ship-handling with the assistance of SWOS's Bridge and Combat Information Center (CIC) Team Trainer. The simulator, which is designed to train officers on how to stand watch in all of the required stations on a ship's bridge and in a ship's CIC, exposes the students to several critical ship-handling evolutions such as open ocean transits, formation steaming, UNREPs, man overboard, and harbor transits. However, due to its inability to allow twin-screw ships to operate with different engine orders, the simulator currently cannot conduct extremely complex ship-handling events, such as pier work. Moreover, the trainers cannot correctly reflect the effects that the winds, currents, and shallow water have on the ship. [SWOS98]

To compensate for the inability of their in-house ship-handling simulator to handle complex scenarios, SWOS spends a considerable amount of money sending its students to the Marine Safety International (MSI) facility where they are exposed to more complex ship-handling scenarios. MSI is a commercial operation run by retired navy captains. These simulators are constructed in two different manners. One simulator is a room sized bridge mock-up that is used for harbor transiting and pier side ship-handling. The second simulator is a replica of a standard bridge wing, which is used for man overboard and underway replenishment scenarios. The MSI simulators, even with locations on both the East and West Coast, are in high demand. For not only are they used by SWOS students, but are also available to other navy ships and commercial mariners. In fact, students who attend the six-month department head class, only receive 10 hours of training and must wait until after eight o'clock in the evening before they can use the simulator at MSI. Although the simulators at MSI provide an excellent training tool for ship drivers, they are extremely expensive to operate. Therefore, with the cost of sending bridge teams to use the facilities reaching as high as $2,000 for two nights of service, smaller ships with limited training budgets cannot afford to send all of their officers through this type of training.

C. CURRENT RESEARCH

Computer-driven ship-bridge simulators have been around since the 1960's. However, rapid advancements in technology have allowed these simulators to evolve from being limited-task to multi-task and full mission simulators. The following section is a review of the current projects, military and commercial, that are being developed in support of VE based ship-handling systems including the Navy's COVE and VESUB projects as well as the commercial projects that are available to merchant mariners.

1. Conning Officer Virtual Environment (COVE)

Considered to be the future training tool for all surface warfare officers, the COVE system is being designed to train surface warfare officers in both the art and science of ship-handling. COVE is also being developed to allow for maximum portability, such that it will eventually be used not only at SWOS, but on deployable ships as well. In response to SWOS's need for an alternative method in training its students in ship-handling, the Office of Naval Research (ONR) is sponsoring the Virtual Environment Training Technology (VETT) project, which is being conducted by NAWCTSD researchers and assistant scientists. [NORR98] The VETT program, initiated in 1993, is designed to develop, demonstrate, and evaluate virtual environment technology for training applications. Therefore, the primary goal of the VETT research is to provide a testbed system that can be used to demonstrate how well ship-handling skills trained in a virtual environment transfer to real world situations.

Figure 1. View of COVE prototype during mooring evolution.

One of the primary requirements defined by SWOS is to have a "performance-driven system" that trains ship handlers in acquiring a seaman's eye. Therefore, the greatest challenge of the COVE system is to accurately display the visual cues a conning officer would utilize in the real environment. This challenge is successfully met by the use of COVE's head mounted display (HMD) that presents a full 360 degree field of view which closely resembles the view a conning officer would see if he were on an actual ship. Unlike large expensive bridge simulators currently being used at SWOS, the use of the HMD enhances the feeling of "presence" by the subject. Presence is often referred to as the ability for one to feel that they are really in the world that is being represented by the computer other than their true physical location. [STEU92]

Another key requirement the COVE system addresses is the ability to reduce instructor intensiveness. Currently, in order to correctly operate one of the bridge mock-up simulators, human experts are required to be present so that they can evaluate each individual student's performance. However, the COVE system is being developed to provide state of the art intelligent tutor techniques that will allow multiple students at individual stations to be evaluated simultaneously. The intelligent tutor aspect of COVE would not only allow the students to use the simulator at their own convenience, but would also provide immediate feedback and constructive criticism.

The COVE prototype simulator currently provides a ship-handling scenario for an underway replenishment (UNREP) evolution between an Arleigh Burke Class destroyer and an AOE-6 class auxiliary ship. In addition, scenarios for pier work and amphibious landing evolutions are also in development. Researchers from NAWCTSD are also continuing to conduct experiments with the intelligent tutor to evaluate its integration within the virtual environment.

2. Virtual Environment for Submarine Handling Training (VESUB)

Experiencing similar deficiencies in ship-handling training as the Surface Warfare Community, the United States Navy's Submarine community has also found a need for an alternate training method for its officers standing OOD watches on submarines. Due to extremely limited resources to properly train submarine officers in the art of ship-handling, the submarine community asked NAWCTSD researchers to develop a system that would integrate the already existing Submarine Piloting and Navigation (SPAN) training simulator with a stand-alone virtual reality-based system. [NAVA98] This system became known as the Virtual Environment for Submarine Handling Training (VESUB). VESUB's concept and objectives are similar to those of the COVE simulator in that it provides the student an opportunity to acquire much needed ship driving experience while reducing the instructor workload. It also utilizes a HMD, which presents a simulated 360-degree visual environment containing all of the required cues associated with harbor transits under varying environmental conditions. [NAVA98]

Originally developed as an exploratory system designed to evaluate the potential of training submarine officers in a virtual environment, VESUB has received excellent reviews by the submarine community. Due to its success, it is now being used as the foundation for the VESUB 2000 procurement.

3. Commercial Systems

Unlike the Navy's surface warfare community, the commercial maritime industry has been utilizing computer-based simulators to train ship-handling since the early 1990s. [COMM96] Due to the increased public concern for maritime safety and the recent trend of smaller crew sizes onboard merchant vessels, commercial mariners also began to integrate marine simulation into their mariner training programs.

Contrasting the highly structured environment of commercial air carrier simulators with its well-defined classifications and standards, the marine industry is just now developing a standard terminology for describing simulators. The International Maritime Organization (IMO) proposes a simulator classification system that separates maritime simulators into four major categories: 1) full-mission, 2) multi-task, 3) limited-task, and 4) special-task. [COMM96] Full-mission and multi-task simulators place the trainee inside a bridge mock-up with actual bridge equipment or fully functional and configured emulations of bridge equipment. Limited task simulators place the trainee inside a training environment that is more limited in its capabilities to simulate navigation and harbor transits. And finally, special task simulators are similar to limited task simulators except that the trainee is located outside of the environment (i.e. sitting behind a desktop computer).

Today, there are many commercial organizations that provide training to both merchant and military mariners through the use of their full mission or multi-task bridge mock-up simulators. One such company, Ship Analytics, offers a Full Mission Shiphandling Simulator that provides a 360 degree viewing area, visual environmental effects, and a comprehensive list of ship-handling scenarios ranging from basic to very complex evolutions. In addition, Ship Analytics also provides a performance monitoring and evaluation system that allows the trainee to receive a thorough review of his performance. [SHIP00] Ship Analytics serves many commercial mariners and, on a limited basis, navy and coast guard teams in the Pacific Northwest region.

Recognizing the outstanding capabilities that commercial maritime simulators offer, the Navy's surface warfare community continues to use these services as a supplemental ship-handling training tool not only for its officers who attend SWOS but those serving in the fleet. Unfortunately, the high operating costs and limited availability of these commercial simulators make them an unfeasible long term option. The reason behind this negative outlook is that most ships have very limited training funds and cannot afford to send many of their officers, if any at all, to these commercial sites. Since only a small number of officers serving in the fleet are able to actually use these commercial simulators it is inevitable that the future ship-handling tool for surface warfare officers will resemble the COVE simulator.

C. COGNITIVE TASK ANALYSIS

As previously discussed, there are a number of ship-handling simulators that are used to improve the ship driving performance of the "novice" trainee. Yet, in order for these simulators to be successful, their developers must understand how proficient individuals, "experts," perform the task of ship-handling. By studying in detail the general knowledge, specific information, and reasoning processes an expert uses, a model of the task can be constructed that exhibits some of the properties of the expert being modeled. [KCMC88] Although there is no standard way of obtaining this information, one method, in particular, has been successful in capturing the necessary knowledge and processes that are utilized by the expert in his particular domain. This method is known as a cognitive task analysis.

1. Definition

A traditional behavioral task analysis is generally defined to be the direct observation of a person performing a certain action, in which the data gathered from this observation is then used to describe, in detail, the tasks needed to accomplish a specific goal. A cognitive task analysis, however, seeks to relate the behavioral concerns of a traditional task analysis with the internal knowledge concerns of cognitive science. [ZRHC99] Thus, a cognitive task analysis not only elicits the explicit knowledge of an expert, but it also examines the way the expert tries to accomplish the specific task through his perceptual and information-processing abilities.

2. Applications of a Cognitive Task Analysis

Cognitive task analyses have been used in many ways to improve the quality of human performance in decision making tasks. Some of these applications include, studying the differences between novices and experts so that predictions of performances can be modeled, evaluating expert systems, and analyzing skilled performance for identifying training requirements. Cognitive task analyses have also been used in the development of executable cognitive models in a complex real-time domain. Additionally, cognitive task analyses are used to study team decision making and situation awareness. CHI Systems, Inc. recently developed a cognitive task analysis that was used to model team decision making for an intelligent tutoring system, the Advanced Embedded Training System (AETS). [ZRHC99] The scope of the AETS application required that the cognitive task analysis and resultant executable cognitive model deal with the full range of individual activity in a ship's combat information center, from high-level strategy to low level keystroke sequences. The significance of this project showed the flexibility of a cognitive task analysis in that the expert performance data was collected for an entire team and not just an individual expert.

D. SELECTING A COGNITIVE MODEL AND ELICITATION METHOD

There are two key challenges in conducting a task analysis: 1) selecting an appropriate cognitive representation, and 2) choosing an efficient knowledge elicitation method. Selecting a cognitive representation is made difficult because there is currently no standard model that is universally used in constructing cognitive task analyses. Oftentimes a model is chosen due to the nature of the task that is being analyzed. Additionally, since the cognitive task analysis process is continually refined with every iteration, the selected model must be able to efficiently handle the constant updating of information.

In selecting a knowledge elicitation method, problems arise in many areas as well. One area of concern is with the experts themselves. Experts have implicit knowledge of how to perform a task, but they do not always have the explicit knowledge about how or why they perform the way they do. For example, when an expert ship-handler was asked to explain how he knows when a ship is far enough away from the pier so that its stern will not collide with it when the ship is getting underway, he responded with, "I can't explain it. I just know when it is." Another area of concern is the tendency to emphasize explicit knowledge, yet overlook the contribution made by implicit knowledge and by perceptual learning. Knowledge elicitation methods should describe the function served by implicit knowledge in proficient task performance so that it should not appear that explicit knowledge is sufficient for proficient performance. [KCMC88]

For this thesis, two distinct methods were chosen to elicit and represent the task analysis of pier side ship-handling. A GOMS (Goals, Operators, Methods, and Selection rules) model was selected to provide the detailed structure for performing the pier side ship-handling task, which would represent the "science" of pier side ship-handling. It would present a logical sequence of procedures that must be completed in order for one to successfully perform a standard pier side evolution. The Critical Decision Method (CDM) [HOFF98] was used to efficiently elicit expert knowledge, since it provided the necessary procedures to conduct comprehensive knowledge elicitation. In addition, it allowed the knowledge elicitor to compile a Critical Cue Inventory (CCI) of the key perceptual cues that were used for the task of pier side ship-handling. Together, the Cue

Inventory and GOMS notation address the implicit knowledge of the expert ship driver and represent the "art" of pier side ship-handling.

E. GOMS MODEL

Developed as an information processing theory of human-computer interaction, GOMS is a useful method for describing a specific task through the specification of the procedures a user must perform to successfully complete the task. GOMS is based on the principle that behavior can be described as a model using four constructs: Goals, Operators, Methods, and Selection Rules. [MRTZ95] The Goals represent the user's primary goal, or the desired final state. For example, the primary goal of a conning officer during pier side evolutions would be either to get the ship underway or moor it to the pier. Operators represent the actions or subgoals used by the individual to achieve the primary goal. In the case of ship-handling, an operator would be the orders or commands given by the conning officer. Methods are the procedural sequences of operators designed to accomplish the goal. For instance, the method of giving a verbal rudder order to a helmsman would be to specify the direction the rudder should be moved followed by the amount of rudder angle desired. Finally, Selection Rules are the rules by which the user chooses in deciding what method to use when there are multiple methods available to accomplish the goal. For example, there are many ways in which a conning officer can execute a port turn. However, if the situation required that the ship be turned around as quickly as possible, the conning officer would then choose the turning method that satisfies the rule for turning the ship quickly, like the method of using a "left 30 degrees rudder."

1. Why use GOMS?

There are many reasons why someone would want to use a GOMS model. For one, a GOMS analysis is very successful in its ability to produce models of human behavior and make predictions of user performance. It can also be used to predict not only the sequence of operators a user will perform, but the also the time it takes to complete the given task. Additionally, GOMS analyses can be used to evaluate systems or design ideas, focus design effort, suggest redesigns, and even structure user documentation. [JOHN95]

The GOMS approach is useful in that it is a very easy concept to learn and modify. For example, several academic GOMS researchers have successfully taught the technique in a few lectures to CS undergraduates in introductory HCI classes. [JOHN95] GOMS models are so simple that they can be built by hand, or with generic tools such as spread sheets or word processors. Even though researchers are trying implementation of GOMS models with sophisticated computational cognitive architectures such as SOAR or COGNET, its relative simplicity and ease of learning were the main reasons it was selected for this thesis.

GOMS is also quite flexible. Allowing easy modifications to its structure and layout once changes occur, GOMS affords flexibility for the various stages of refinement during the knowledge elicitation process. In addition, the fact that there are at least four different versions of GOMS in use today reinforces its flexible characteristic. One version is the Keystroke-Level Model (KLM), which was developed by Card, Moran and Newell. The KLM, a simplified version of the their original GOMS formulation (CMN-GOMS), uses keystroke-level operators where the only thing listed in the model are the keystrokes a user must perform to complete the task. Another version is the "Natural" GOMS Language (NGOMSL) which was proposed by David Kieras. [KIER94] NGOMSL is similar to a computer programming language that provides very detailed procedures and rules of thumb the operator must use. Additionally, there is a parallel-activity version called the Critical Path Method (CPM)-GOMS which was developed by Bonnie John and uses cognitive, perceptual and motor operators to show how activities can be performed in parallel. [JOHN95] What this family of GOMS models offers is the flexibility to fit a wide range of cognitive task analysis applications. As this thesis will also demonstrate, GOMS is a suitable method of representation for various knowledge elicitation methods.

2. Shortfalls of GOMS

Despite the many uses and flexibility of GOMS, there are a few areas in which it does not provide sufficient results. One area in particular is GOMS' inability to predict problem-solving behavior. What this means is that although it can predict what the sequence of operators will be for a given task and present it in a structured manner, it has problems explaining what the expert was thinking when accomplishing each task. For example, a GOMS model may show that an expert ship driver may take the action of shifting his rudder because he observed the distance between the ship and pier decreasing. However, what the GOMS model fails to show is what perceptual cues or implicit knowledge the conning officer was using to determine the change in distance. Therefore, since the task performance of a conning officer conducting pier side ship-handling evolutions requires perceptual knowledge which GOMS does not account for, another knowledge representation technique must be used in conjunction with a GOMS model.

3. GOMS Notation

So how are GOMS models described? Created in a similar fashion as an outline, the primary goal, or task to be modeled is identified first and positioned on the first line of the model. Next, the sub-goals, or operators, of the primary goal are then established. They represent the next immediate steps that must be satisfied in order for the primary goal to be accomplished. These sub-goals are positioned underneath the primary goal in the sequence that they occur during the task. The sub-goals are then broken down even further into the respective methods that are used to accomplish them. In order to represent the hierarchical relationship between the primary goal and its sub-goals and methods, the dots at the left of each line show the depth of the goal stack. [CARD83] If there are multiple methods for accomplishing a specific subgoal, a selection rule is annotated to the right of the subgoal to indicate why the user would choose one method over the other. An example of the CMN-GOMS notation is shown in Figure 1.

```
. . . goal: Adjust_Rate_Of_Swing_Of_Stern
. . . . goal: Increase_Rate_Of_Swing                 ...if rate determined too slow
. . . . . [select: Increase RPM on port engine          ...swing direction is stbd
. . . . .          Increase RPM on starboard engine     ...swing direction is port
. . . . .          Increase RPM on both engines]        ...swing dictated by rudder
. . . . goal: Decrease_Rate_Of_Swing                 ...if rate determined too fast
. . . . . [select: Decrease RPM on port engine          ...swing direction is stbd
. . . . .          Decrease RPM on starboard engine     ...swing direction is port
. . . . .          Decrease amount of rudder being used] ...swing dictated by rudder
```

Figure 2. Example of CMN-GOMS Notation.

Depending on the desired level of detail needed from the task analysis, which Card, Moran, and Newell referred to as the "grain of analysis," the GOMS model can be composed having more or less detail. In accordance with the CMN-GOMS notation, three model levels were utilized in this thesis: the Unit Task Level, the Functional Task Level, and the Detailed Task Level. The lowest level of detail is presented at the Unit Task Level. Here the primary goal is identified along with its immediate sub-goals or operators. The Functional Task Level decomposes the Unit Task Level and represents the next level of detail. The Detailed Task Level, much like its name, provides the greatest degree of detail among the three models. By further decomposing the methods used at the Functional Task Level, the Detailed Task Level begins to show the sequential nature of the GOMS model.

F. CRITICAL DECISION METHOD

The Critical Decision Method (CDM) was used for this thesis as a guide in eliciting knowledge from expert ship handlers. Originally derived from J.C. Flanagan's Critical Incident Technique [FLAN54], Klein, Calderwood and MacGregor developed the CDM process. [KCMC89] It involves having experts recall and retrospect about a critical or non-routine incident. What makes the CDM different from other knowledge elicitation methods is that by continuing to ask the experts probing questions concerning specific events during the incident, it is able to progressively uncover many perceptual cues used in the decision-making process.

1. CDM Process

Once a specific task or critical incident is selected, the CDM technique elicits the expert's knowledge in three distinct phases. The first phase establishes the order of events or procedures that took place during the task. This is accomplished by allowing the expert to recall the entire event without being interrupted. Once the expert is finished, the interviewer then retells the story and tries to arrive at a common understanding of the incident. The second phase of the CDM leads to a more comprehensive and "contextually rich account" of the incident. [HOFF98] As the expert goes through the task a second time, the interviewer tries to identify "decision points," which are specific points in the incident where the expert makes judgements that affected the outcome. The third phase of the CDM process has the expert go through the event for a third time. During this phase the elicitor asks the expert a number of probe questions in an attempt to get even more detailed information about the incident. The interviewer also inquires about the informational cues that were used in the initial description throughout. In addition to the probe questions, the elicitor poses various "What if" questions to identify any inaccuracies, differences between experts and novices, and any alternative methods. [HOFF98]

2. Critical Cue Inventory

As mentioned earlier, one of the key benefits of the CDM is its ability to generate a list of perceptual cues used during the task or critical incident. Since many of these cues are not always considered to be relevant by the expert, they are often not discussed until the final two phases of the CDM. For example, when experts were asked to first describe the task of getting a ship underway from a pier, they often failed to mention the perceptual cues that they used in making an initial assessment of the environmental effects on the ship. It was only after asking how he determined the current of the water that he began to explain his use of visual cues, such as wakes being made by the channel buoy, to make an assessment. Table 1 is an example of how a CCI can be constructed. This example shows a set of cues reported by medical personnel for recognizing

Critical Cue Inventory: Early Warning Signs of Cardio-Pulmonary Distress	
Cue Category	*Description*
Skin tone	changes in skin color (skin losing pinkness and becoming blue/grey), especially at extremities
Eyes	glazed, unfocused look; pupils may be dilated
Skin	cold, clammy feel: sweaty, greasy
Breathing	may be rapid, shallow breathing may show "air hunger"; struggling to get air into lungs; a crackling, bubbling noise at both inhale and exhale

Table 1. Example of a Critical Cue Inventory. [KCMC88]

early signs of cardiopulmonary distress. The CCI not only provides a comprehensive list of all of the key perceptual cues utilized during the task but also provides a tool in which cue elements can be associated with other types of similar tasks. For this thesis, the CCI was used to supplement the pier side ship-handling GOMS model with the perceptual cues of an expert ship driver. This enables the cognitive task analysis to examine not only the way the expert performed the task, but why he chose a certain method over another.

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III. TASK OVERVIEW

A. BASIC SHIP HANDLING FUNDAMENTALS

Before presenting an overview of the task of pier side ship-handling, it is imperative that this thesis examines the fundamentals of ship-handling in order to provide a basic foundation for readers unfamiliar with the skills and theories of ship driving. This overview will focus on the science aspect of ship-handling by discussing the types of forces that act on a ship and how the ship responds to these forces. It will also discuss the standard commands used during pier side evolutions as well as those that are involved with pier side evolutions.

1. Forces Affecting the Ship

There are six general sources of force, which can affect the movement of a ship through the water. They are the propellers, the rudders, the mooring lines, the ground tackle, the wind, and the current. The first four are controllable from the ship itself. The wind and the current, though not controllable, can be utilized to manipulate the ship's motion. Although volumes can be written about each force, the focus here will be to describe in general terms, how these forces affect the ship and how a ship responds to them. Since pier side ship-handling extensively uses all six of these forces, a competent conning officer must thoroughly know and understand them.

A ship's propeller provides the thrust that drives the ship through the water. However, it does not only affect the ship in the forward or backward direction. As the propeller turns through the water it produces a side force at the stern of the ship which is quite appreciable. [CREN75] The side force, which varies depending on the type of the ship, represents the direction of rotation of the propeller. For example, a propeller turning left will tend to force the stern to left. Figure 2 clearly illustrates how the side force affects the stern of the ship. Side forces created by the propeller are very useful to a conning officer during pier side evolutions because at very slow speeds the ship's rudder becomes ineffective. Therefore, the conning officer has the ability to maneuver a ship with its engines and propellers alone.

The rudder, located astern of the propeller, provides the primary steering force needed to turn the ship. We actually steer the ship by setting the rudder at various angles

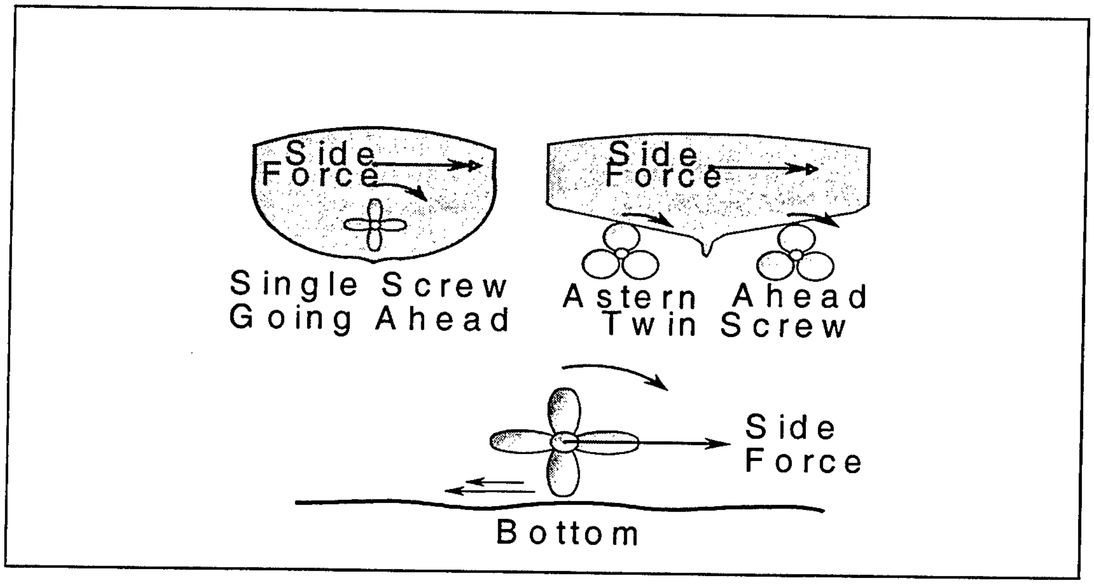

Figure 3. Side Force on a propeller as viewed from astern of the ship

with respect to the centerline of the ship. [CREN75] Applying right rudder, when moving ahead, will force the bow of the ship to move to the right by forcing the stern to swing to the left. A left rudder order will move the bow to the left. This technique, however, does not work well when the ship is nearly dead in the water. Below a certain speed, oftentimes considered to be 1 knot, a rudder is unable to overcome the forces working on the ship. This is known as a ship losing "steerageway." When the ship has lost steerageway, its heading can no longer be controlled by the rudder alone and must be steered by the use of the propeller. [CREN75]

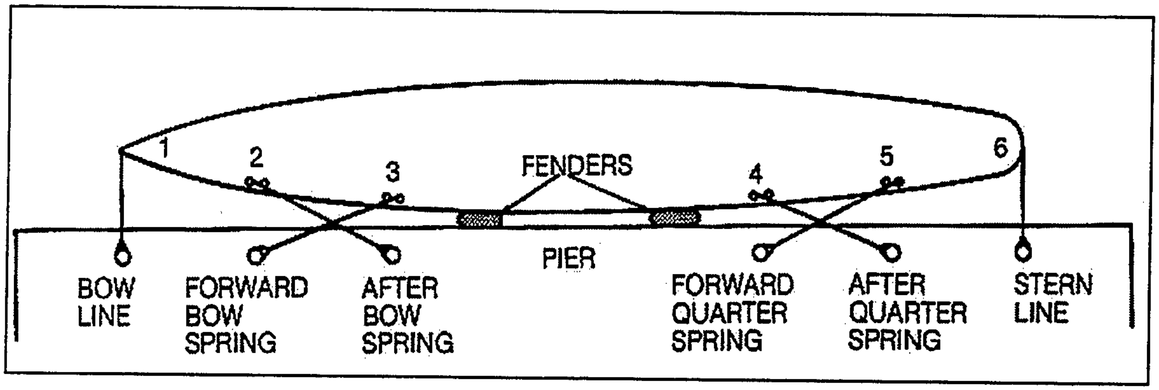

Figure 4. Standard Mooring Line Configuration

Mooring lines not only provide the method in which a ship is moored to a pier, but are also used in positioning the ship alongside a pier. Figure 3 illustrates the standard mooring line configuration used by most navy ships when they are tied up to a pier. Larger vessels, such as aircraft carriers and amphibious ships, utilize a different line configuration, and can use up to 12 mooring lines. A "breast line" controls the distance of that part of the ship from the pier. A "spring line" controls the forward and aft position of the ship with respect to its "berth," the ship's designated position on the pier. During pier side evolutions, mooring lines are used by the conning officer to work the ship in against the pier as well as in situations where it is necessary to hold the ship in a particular position. For example, a conning officer may need to get a ship underway from a pier but has another ship directly in front of him. To prevent the ship from hitting the ship in front, the conning officer could use the after bow spring line to hold the ship's position while the stern is swung out away from the pier.

Another important force acting on the ship is the wind. The wind affects the ship by blowing on its "sail area," the structure above the waterline, and moving the ship downwind. Although the wind can present many problems for the conning officer, it can also be very useful. For example, a ship can clear a pier without using its engines or rudder, by simply taking in all of its mooring lines if the wind' s direction is blowing the ship away from the pier. However, since the side forces available from the propeller is relatively small, if the wind is very strong, a considerable amount of headway, or forward motion of the ship, is needed before the additional force from the rudder is sufficient to overcome the wind. Additionally, the act of maneuvering a ship under windy conditions is also made difficult due to its constantly changing direction and magnitude.

Finally, there is the force due to current that has an affect on the ship. Current, defined as the movement of the water, affects the ship's body under the water and carries the ship along with its directional flow. The force resulting from a current is much larger than that resulting from wind because the density of the medium is much greater. [CREN75] A common rule of thumb used by conning officers is that 1 knot of current is equal to 15 knots of wind. To overcome the affect of currents, a conning officer must be able to efficiently predict how much he should compensate for it. For example, if a ship is making its approach to the pier where a current is flowing from right to left at 1 knot, the conning officer knows that the ship will be swept away from the pier by the current. Therefore, he must compensate for the current by positioning the ship further to the right of the pier.

Until a ship handler fully understands the forces that act on the ship, and how they can be controlled, he will have a difficult time maneuvering the ship.

2. Pivot Point

With a general understanding of all of the forces that may act on the ship, the next area of discussion is how the ship reacts to the application of these forces. As mentioned earlier, turning the ship is a result of moving the stern from side to side through the use of the propeller and rudder. The point about which the ship turns when the rudder is put over is referred to as the pivot point. [NOEL84] Since the location of the pivot point varies between ship types, it is imperative that the conning officer is familiar with the position of his own ship's pivot point so that he can reference it while making turns in harbors and pier areas. For instance, when a ship departs the pier area and makes a turn out into the channel, the conning officer will not put his rudders over until the pivot point of the ship is beyond the head of the pier. If he doesn't do this, the ship runs the risk of clipping the head of the pier as it makes its turn. The location of the pivot point also changes depending on the direction of the engines and how the ship sits in the water. Normally, when the ship is making headway, the pivot point is in the forward one-third length of the ship. If the ship is making sternway or going backwards, the pivot point can

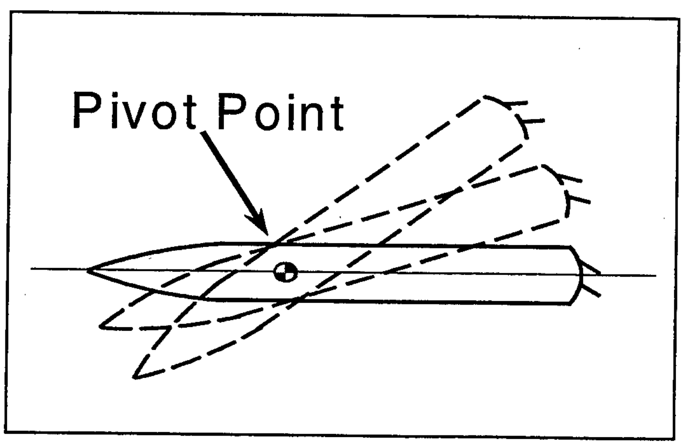

Figure 5. Pivot Point of a Ship Twisting.

shift as far back as being just forward of the rudders themselves. Additionally, the heavier the ship the farther aft the pivot point will be.

2. Twisting

During pier side evolutions, it is often required to be able to turn the ship in a very confined area. To accomplish this, the ship handler tries to "twist" the ship about the pivot point with little or no headway or sternway. A conning officer has a couple of options in twisting the ship. One option is to twist the ship by using a combination of the engines and rudder. Ships that have twin screws, or propellers, can twist by utilizing opposing forces of their screws. For example, in order to twist to the left, the conning officer would put the rudder over to the left and order a "backing" bell on the port screw and an "ahead" bell on the starboard screw. The resulting motion has the ship twist slowly to the left about the pivot point of the ship. An interesting technique used to teach young ship drivers how to twist ship with multiple screws is called the "bicycle theory." The conning officer imagines he is holding on to the handle bars of a bicycle. He then mentally turns the handle bars as if he were making a left turn on the bike. The resultant position of his hands on the handle bars represents the direction the ship's engines should be in order to twist the ship to the left. In this example, the conning officer's left hand ends in the back position so the port engine should be order "back." His right hand is forward, so the starboard engine should be ordered "ahead." Ships that only have one screw, such as frigates, twist with the assistance of their auxiliary power units (APUs) which are small, rotating thrusters located underneath the bow.

3. Standard Commands

In conducting pier side evolutions, it is imperative that the conning officer not only know all of his standard engine and rudder orders (see Appendix A), but he must also be fluent in the commands used exclusively for mooring to or getting underway from a pier. Like standard rudder and engine commands, orders given to line handling stations are given in a specific sequence. In order to prevent confusion, each order given by the conning officer to the line handling stations should be succinct, clear, and consistent.

Because misunderstanding or ambiguity can quickly lead to disaster, there must be no possibility of an order being misinterpreted. [NORR98] A list of orders given to the men at the line stations appears in Table 2, with explanations of each.

SEND THE LINES OVER:	Pass the lines to the pier, place the eye over the appropriate bollard, but take no strain.
TAKE A STRAIN ON ONE:	Put line number one under tension.
SLACK ONE:	Take all tension off of line and let it hang slack.
TAKE LINE __ TO THE CAPSTAN:	Lead end of line the capstan, take slack out of line, but take no strain.
HEAVE AROUND ON LINE:	Apply tension on line with capstan.
AVAST HEAVING:	Stop the capstan.
CHECK LINE:	Hold heavy tension on line but ease out to prevent parting of the line.
SINGLE UP:	Take in all bights and extra line so there remains only a single part of each of the normal mooring lines.
DOUBLE UP:	Pass an additional bight on all mooring lines so that there are three parts of each line to the pier.
TAKE IN ALL LINES:	have the ends of all lines cast off from the pier.

Table 2. Standard Orders to Line Handling Stations.

4. Pilots and Tug Boats

Most harbors and naval shipyards have regulations that require that a licensed harbor pilot must move all ships when within certain defined waters. The pilot, a master in ship-handling, is very familiar with the local channel conditions, provides assistance to the ship's commanding officer and bridge team in pier side evolutions. He knows the entire harbor ranges, the landmarks, and the habits of the local shipping. Despite the many years of ship driving experience, the pilot is not necessarily an expert on the ship's handling characteristics. Therefore, it is imperative that the commanding officer and conning officer, who are familiar with the ship's characteristics, work together with the pilot during pier side evolutions.

The companion of the pilot is the tug. [CREN75] Tug boats are used to assist in getting ships in and out of tight places. Designed to be able to push or pull through the combination of its engines, rudders, and lines, a tug can produce a force in almost any

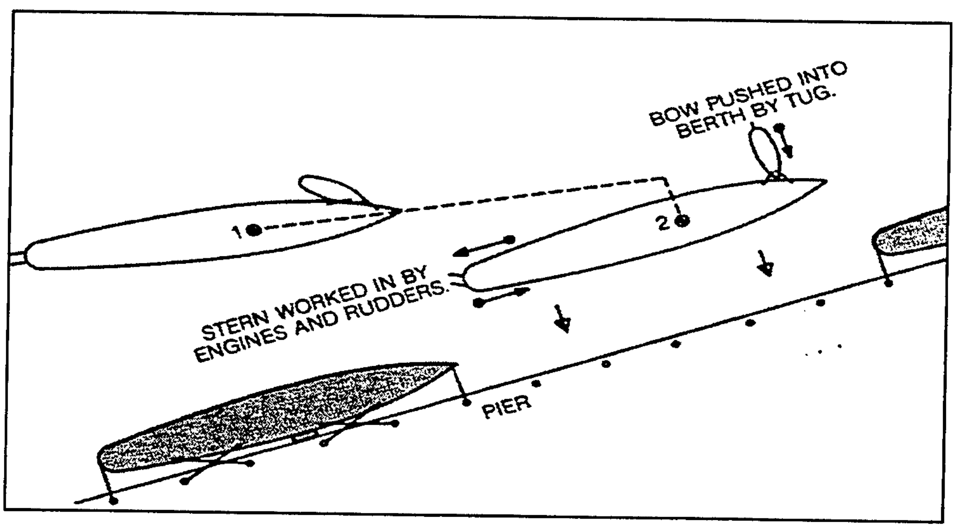

Figure 6. Example of berthing a ship with a single tug.

desired direction. The pilot, who passes intructions to the tugs via a hand held radio, usually controls the tugs. Used exclusively by larger ships that are unable to maneuver by themselves in the pier area, tugs also aid smaller ships in getting into extremely tight berths. Normally secured to the forward portion of smaller ships, tugs help control the movement of the ship's bow as well as keep the ship from hitting other objects when entering or leaving the berth area.

5. Restricted Maneuvering and Emergency Responses

During critical ship-handling evolutions, such as mooring to a pier, the Navy has required that all ships follow specific procedures in order for them to respond quickly to any type of casualty that may occur. These procedures, known as the Restricted Maneuvering Doctrine, specifies a certain engineering plant configuration that places all machinery critical to propulsion and steering online and made available. For example, prior to getting underway or entering port, all available engines, generators, and steering units are put into operation. Under normal steaming operations, if a ship were to lose an engine or steering unit, it may take several minutes to get a back-up unit running and operational. However, during a restricted maneuvering situation, if a casualty does occur, the configuration of critical machinery allows stand-by units to be automatically shifted over to cover the loss of the primary units.

A restricted maneuvering situation exists when a ship is restricted in its ability to maneuver due to being very close to shoal water or other ships. During this situation it is imperative that the ship be able to maintain control of its propulsion and steering units, otherwise, it runs the risk of colliding with another ship or running aground. The Restricted Maneuvering Doctrine also requires additional stations to be manned that are normally not manned during standard operations. For example, during restricted maneuvering situations, a qualified helmsman and conning officer are stationed in the after steering room to provide an alternate means of controlling the rudders in the event steering is lost on the bridge.

Although casualties rarely happen during these evolutions, the conning officer must be prepared to handle them in the event they do. The following is a list of casualties or emergencies that are specific to pier side evolutions and may be encountered by the conning officer.

- **Loss of steering**: A condition in which the helmsman loses his ability to control the ship with the rudder. This casualty is usually indicated by an alarm on the helm console sounding off and the indicator light to the steering unit in operation flashing on and off. Another indication is that the rudder does not respond to the action of the wheel being turned by the helmsman. The response of the conning officer is to immediately shift to the stand by steering unit. If the rudder still does not respond, an alarm is sounded in the after steering station where the personnel immediately take local control of the rudder. If after steering is still unable to control the rudder, the conning officer can use the engines and assisting tugboat to maintain the ship's position while the mechanics fix the problem. However, if it appears that the ship begins to drift towards other ships or shoal water, the conning officer can let go of the anchor to keep the ship from drifting into a hazard.
- **Loss of propulsion**: Caused by the loss of the engines. Since the speed of the ship is very slow during pier side evolutions, the only indication that the

conning officer may have is the call from the Engineering Officer of the Watch (EOOW) reporting the casualty. In addition, with no water flow over the rudder the ship will rapidly lose its steering capability. Therefore, the only option the conning officer has is to use the assisting tug to hold the ship's position or let go the anchor.

- **Loss of gyrocompass repeater**: Caused by the loss of the gyrocompass. The most common indication to the conning officer will be that the gyrocompass alarm will sound on the bridge. Other indications might be that the gyrocompass repeater will not move with the changes in the ship's direction or begins to spin wildly out of control. Although this is the primary means for monitoring the ship's heading, the conning officer must shift to using the magnetic compass, which is normally located next to the gyrocompass repeater.

B. PIER SIDE HANDLING OVERVIEW

Pier side ship-handling is one of the most basic, yet extremely critical, evolutions performed by a conning officer. It is also one of the most rewarding evolutions. For if a conning officer can smartly and safely accomplish a pier side evolution, it demonstrates to his peers how good of a ship driver he or she really is. Successfully accomplishing this evolution, however, takes planning, advance preparation, training, and the teamwork of everyone involved. [DODG81] Therefore, conning officers must be prepared and sufficiently trained to be able to successfully conduct pier side ship-handling evolutions.

Getting a ship underway from a pier and mooring a ship to a pier make up the two fundamental components of pier side ship-handling. Since navy ships cannot stay underway forever, they must periodically return to port so that they can receive needed repairs and supplies, as well as allow their crews to receive some rest and relaxation. Unlike special sea evolutions such as underway replenishments or plane guard assignments to aircraft carriers, which don't always take place when a ship is at sea, pier side evolutions happen every time a ship enters and leaves port.

Pier side evolutions are very complex in that they require the ship-handler to be very knowledgeable in many areas including the ship-handling characteristics of the vessel and the effects the environment impose on the ship. The conning officer must fully understand the general principles involved with pier side ship-handling to be successful. Additionally, he must be able to anticipate what action must be taken next and immediately recognize when something appears incorrect.

1. Getting Underway from a Pier

Getting underway from a pier is usually the easier of the two pier side evolutions. This is because unless there is a current or wind forcing the ship up against the pier, it takes very little effort to maneuver the ship out away from the pier. Although the presence of wind or currents can make this evolution more challenging, the steps to get a ship safely underway are very straight forward.

Typically, the first step in getting underway from a pier is to ensure that the ship is ready to go to sea. This preparation phase is very comprehensive. Each of the ship's departments have a check list that outlines, in detail, everything they are required to do to get the ship ready for sea. For example, the engineering department is not only responsible for getting the ship's propulsion and steering systems ready, but is also in charge of disconnecting and removing all of the shore services, such as water, electricity, and sewage lines, which are needed by the ship while it is inport. The check lists are usually started at least 48 to 72 hours prior to the scheduled underway time. Once a department completes its check list, the respective department head reports to the ship's executive officer and informs him that the department is ready to get underway.

Generally, an hour before the ship is scheduled to get underway, the crew is ordered to man their sea and anchor stations, which represent the watch stations required to get the ship underway. The stations include the bridge watch team, the line handlers, the engineering watch team, and those standing watch in the combat information center (CIC). As soon as all of the stations have all of the required personnel present, each station reports to the officer of the deck (OOD) on the bridge that they are manned and ready.

On the bridge the OOD maintains the ship's official check list and ensures that it is complete before reporting to the commanding officer that the ship is ready to get underway. With the underway check list complete, the harbor pilot on the bridge and the tugboats, if needed, standing by, the ship is now ready to get underway from the pier.

Next, the commanding officer (CO) gives permission to get the ship underway. After doing so, the CO, the conning officer, and the harbor pilot, an expert on ship-handling and local harbor characteristics, position themselves on the ship's bridge wing that faces the pier the ship is moored to. The CO tells the conning officer to give the order to "single up all lines," which means to take in all bights and extra lines so there remains only a single part of each of the normal mooring lines. [DODG81] At this point, by visually checking the tension in the lines, the conning officer is be able to observe if the environmentals are having any effect on the ship. If the lines become slack, it indicates that the ship is being "set on" or pushed against the pier by the wind and/or current. If the tension increases on the lines, then the ship is being "set off" or pushed away from the pier. The absence of any noticeable change in the lines indicates that there is no considerable wind or current acting on the ship. Depending on which situation occurs, the conning officer will apply the appropriate strategy needed to get the ship safely clear of the pier. And although there are numerous strategies for each type of situation, for this thesis, it is assumed that there is no effect on the ship by the wind or current.

Therefore, with no noticeable environmental effect on the ship, the next step is to tie up a tug on the bow, take in all lines, and use the ship's engines to swing its stern out away from the pier. As the stern slowly swings out, the tug is ordered to back down on its engines. By doing this, the bow is moved out away from the pier, thus preventing it from swinging back into the pier. These two actions enable the ship to be maneuvered out away from the pier in a parallel fashion.

Once clear of the pier, the ship is then maneuvered so that the bow is pointed into the direction of the channel. During this time, the conning officer monitors the ship's position in relation to the pier and neighboring vessels, and takes every measure to prevent any risk of collision with them.

Finally, with the ship safely clear of the pier area, the tug boat is cast off. If the pilot is not needed for the remaining harbor transit, he disembarks onto the tug and leaves to assist other vessels needing his services. The ship, meanwhile, continues to maneuver out into the channel and prepares to transit the harbor channel and head out into the open ocean.

2. Mooring to a Pier

The more difficult evolution of pier side ship-handling is mooring a ship to a pier. The reason why is that it presents the conning officer with several challenges that are not encountered when getting the ship underway. The biggest challenge is being able to control the ship's momentum through the water. As it will be discussed later in this thesis, a ship's inability to respond quickly, if at all, to engine and rudder orders at very slow speeds and in shallow water, greatly reduces its maneuverability alongside a pier. Unlike parking a car, the ship driver cannot just put on the brakes and stop the ship. It takes a great deal of time for a ship to come to a complete stop. For instance, the distance it takes an aircraft carrier, doing 20 knots, to stop dead in the water is over 1,000 yards. Therefore, the conning officer must be able to stop the ship in time so that it does not collide with the pier, while at the same time maneuver it into the correct mooring positions.

Similar to getting a ship underway from a pier, the procedures for mooring to a pier are very straight forward. The first step, as it is with getting underway, is to complete all of the preparatory procedures prior to the ship arriving to the entrance of the harbor channel, such as completing the "entering port" check lists and manning up all of the special sea and anchor detail stations. Only when the ship has received permission from the harbor control station and the consent of the commanding officer, will it begin to make the inbound transit of the channel. Depending on the ship's bridge team's familiarity of the channel, the ship will pick up the harbor pilot at the entrance of the channel or right after transiting the channel when the ship is entering the pier area. As mentioned earlier, the purpose of the pilot is to assist the ship's bridge team in navigating the local waters as well as advise them on the particular problems associated with the channel or pier area.

Once the ship successfully transits the channel, the conning officer begins to make his approach towards the pier area. This step, referred to as the approach phase, is very crucial to the success of a mooring evolution. During this phase, the conning officer must accomplish two things: decrease the speed of the ship and maneuver the ship so that it is in the correct position to moor against the pier. If the speed of the ship is not slowed in time, the conning officer runs the risk of colliding with the pier or neighboring ships. If the position of the set up approach is wrong, the degree of difficulty for mooring the ship greatly increases and the conning officer is faced with either backing up and starting over or using tugs to correct his mistake.

The approach position is determined by many factors. These factors include how the ship will ultimately rest against the pier, how the pier is configured, and from which direction the ship approaches the pier. For example, one situation may have the ship moor to the pier "bow out and port side to," which means the port side of the ship is tied to the pier and its bow is pointing out towards the channel. Therefore, if the ship approaches the pier head on, the conning officer would have to "twist" the ship at this point in order to back down into the berth. Additionally, the environmental effects on the ship during this phase also play an important role on the conning officer's maneuvering strategy. For depending on the direction of the winds or currents, the ship may be hindered or assisted in its ability to twist and turn.

It is beyond the scope of this thesis to discuss all of the possible scenarios that a conning officer may face during this phase of the mooring evolution. Therefore, in order to examine the final steps of the mooring evolution let us assume that the ship will moor with its right side against the pier, or “starboard side to.” The pier is located directly ahead of the ship. Additionally, there are no environmental forces acting on the ship.

As the ship closes within approximately 100 yards of the pier, the conning officer will usually decrease the speed of the ship to a one third bell, or less than 5 knots. At the same time he will maneuver the ship so that it is at a 10 to 20 degree angle with the face of the pier. When the distance to the pier is approximately 50 yards, the conning officer will order all of the engines stopped and allow the ship to drift in closer. A minimum headway, or forward motion, should be retained to allow for use of the ship’s rudders. This is known as maintaining “bare steerage way.”

At this point, the strategy of the conning officer is to get the ship as close to the pier as feasibly possible maintaining the 10 to 20 degree angle of approach. Once the bow of the ship is within approximately 20 feet of the pier, the conning officer will order a left rudder to swing the bow away from, and the stern toward the pier. By doing this, the conning officer maneuvers the ship so that its starboard side is parallel to the pier. The order to “send over all lines” is then given to all of the line handling stations, who throw their mooring lines over to the line handlers on the pier.

With the ship’s mooring lines secured to the pier, the ship is then “walked in” towards the pier. Although, this can be accomplished solely with the use of “heaving in” on the mooring lines, most ships utilize the services of the assisting tug boat, which pushes the ship up against the pier. Once the ship is snug against the pier, and properly aligned with the markers on the pier, the order is given to “single-up” all lines. As the stations report that all lines have been singled-up, the conning officer will verify once more that the ship's alignment is still good before ordering the lines to be "doubled-up." With the completion of doubling the mooring lines, the evolution of mooring the ship to the pier is complete.

IV. METHODOLOGY

A. DEVELOPMENT OF THE TASK ANALYSIS

The task analysis was developed in two phases. The first phase was to create a GOMS model to represent the task of pier side ship-handling. The model was initially created by using general procedures presented in several navy publications including the Naval Education and Training Command's NAVEDTRA 10776-A publication, *Surface Ship Operations*, and the Commanding Officer's Standing Orders of two navy ships. A subject matter expert, who had extensive ship driving experience, then reviewed the model. The subject matter expert, using his experience of pier side evolutions, refined the model so that it contained explicit details of the task that were not covered by the publications and training documents. The second phase consisted of validating the GOMS model by interviewing other surface warfare officers using the CDM knowledge elicitation method. Through this process, not only was the model verified and validated, but perceptual cues utilized by conning officers during pier side evolutions were identified. Critical Cue Inventories were constructed and mapped to where they applied in the GOMS model.

B. CONSTRUCTING THE GOMS MODEL

Since pier side evolutions consist of two distinct evolutions, it was necessary to develop two separate GOMS models. One model represents the procedures for getting a ship safely underway from a pier while the other represents the procedures for safely mooring to a pier. The challenge was to construct the two models so that they contained as much detail as possible, yet at the same time be able to represent a generic situation.

As discussed earlier, the procedures and strategies a conning officer utilizes during either one of these evolutions are dependent on a number of factors including the type of ship used, the condition of the weather, and the status of the pier. To model every possible scenario that a conning may face was not feasible for the scope of this thesis. Therefore in order to maintain the scope of this thesis it was necessary to use a generic scenario to model the tasks of the conning officer for each evolution.

1. Scenario for Evolutions

The scenario was developed so that it would be very simple in nature. Generating a generic pier side scenario would allow the GOMS model to be constructed around the basic concepts of pier side ship-handling. Once the basic structure of the model was created, the analysis would then be able to examine the generic scenario further by asking "What if" questions at each basic phase of the tasks in order to address the procedures and decisions used during more complex situations. It was determined that with the majority of the navy's fleet consisting of either twin or multi-screw ships, a twin-screw ship would act as the platform for the scenario since the ship-handling techniques used for both types of ships are very similar. In keeping with the "basic situation" theme, the scenario consisted of having an empty pier for which the ship would get underway from or moor to. Additionally, the environmental effects were made to be negligible by imposing minimal winds and currents.

With identical conditions for both tasks created, each evolution was given its specific scenario. The following are the respective scenarios used in modeling the tasks a conning officer performs during pier side ship-handling.

- **Scenario for getting the ship safely underway from a pier:** A twin-screw ship is moored to a pier on its left side, or "port side to," and its bow facing out towards the channel. There are no other ships on the pier that may hinder the ship's ability to get underway. Additionally, there is currently 1-2 knots of wind and no currents in the pier area. A tugboat, which is delivering the harbor pilot, can be used if the conning officer prefers to have one. With no casualties to its propulsion or steering systems, the conning officer is required to get the fully operational ship underway from the pier, make a left turn at the end of the pier and commence its transit through the harbor channel.

- **Scenario for mooring a ship safely to a pier:** The twin-screw ship has finished its time out at sea, completed its transit through the harbor channel and is now approaching its assigned pier area. The conning officer is to safely moor the ship to the pier where the ship's bow will be facing away from the channel and its right side tied up against the pier. There are no other ships tied to the pier which might hinder the conning officer's ability to moor the ship, and the weather conditions remain the same as they were when the ship got underway. A tugboat will rendezvous with the ship prior to the ship reaching the pier area and deliver the harbor pilot. Again, the use of a tugboat is optional for the conning officer.

2. Developing Models

As mentioned earlier, the first step in developing the models was to identify the general phases of each evolution. By reviewing several ship-handling publications and examining actual Commanding Officer's Standing Orders, the basic phases were identified and organized into a GOMS-like format. A surface warfare officer with extensive experience in pier side ship-handling was then used to provide detailed information on how a conning officer accomplishes each phase. Not only were standard methods identified, but also general rules of thumb were used to describe why a certain method would be performed given a particular situation. The detailed information provided by the subject matter expert was added to the general GOMS-like model and refined by going through each task numerous times. After every review of the tasks was complete, the GOMS model was updated to reflect the new details that were identified.

With the GOMS model complete, the next step was to verify and validate its correctness and accuracy. This step was completed through using the CDM process in interviewing additional surface warfare officers.

C. VALIDATING THE MODEL

In this thesis, ship-handling has been defined as being an art and a science. The idea was that the model would represent the science part of ship-handling. The two models provide the basic theory on how a conning officer would accomplish the respective goals of safely getting a ship underway or moored to a pier. However, like the old saying, "there is more than one way to skin a cat," it was assumed that the two models were not the only way to conduct pier side ship-handling. Therefore, it was necessary to provide additional viewpoints on how to accomplish these tasks. It was determined that the best way to validate the correctness of the model was to solicit other surface warfare officers attending the Naval Postgraduate School and have them provide additional viewpoints as well as validate the two pier side ship-handling models.

1. Participants

Careful consideration was taken in selecting the participants for the validation process. It was known that not every surface warfare officer has the same level of experience or serves on the same type of ships as his peers. For example, there are some officers who have had tours where they were assigned to an engineering billet and did not get to drive the ship as often as those who were assigned to "top side" jobs such as a deck officer or gunnery officer. Therefore, it was determined that the participants must at least have the following criteria: 1) that they have experience with twin or multiple-screw ships, 2) that they have at least 10 experiences of getting a ship underway or mooring to a pier, and 3) that they have recently departed from an at sea tour onboard an operational ship.

As potential participants responded to the requests sent out for volunteers, they were given a questionnaire (see Appendix B) to fill out that asked about their ship driving background, including the type of ships they had served on and how many pier side evolutions they had conducted. From the information provided on the background questionnaires, the participants were chosen by how well they met the defined criteria. This process produced 5 participants of whom all had extensive experience performing pier side evolutions and had recently departed an at-sea command.

2. Visual Aid Model

In order for a surface warfare officer to qualify as an officer of the deck (OOD), he must sit through a comprehensive oral examination, which can sometimes last up to 2 hours. During this examination, the use of visual aids is often utilized to help the qualifying officer walk through different types of situations. For example, a senior officer may create a scenario at sea by using small replicas of ships, usually made out of wood. The senior officer will then ask the qualifying officer to demonstrate how he would maneuver the ship in that given situation by moving the small models around. This same concept was used for the purpose of conducting the validation process. A small model of a pier area and a ship were constructed out of "foam core," or poster board and brought to each of the knowledge elicitation phases. The model was used as a visual aid for the participants as they walked through the pier side evolution and was successful in helping them visualize the scenario. Additionally, the model was advantageous in that it provided a quick and efficient way for the interviewer to reset the problem or stop the expert's account of the evolution at any given position of the ship.

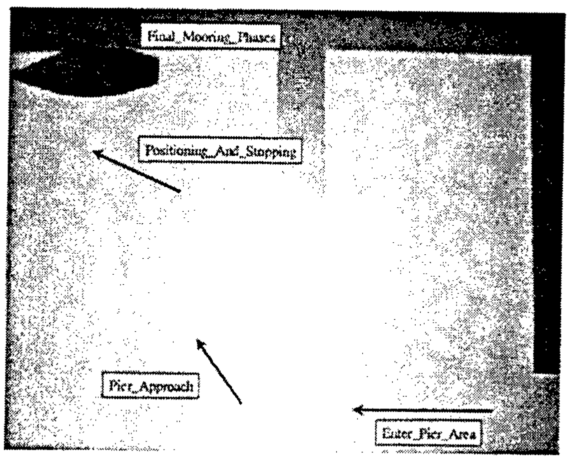

Figure 7. Final mooring position on model.

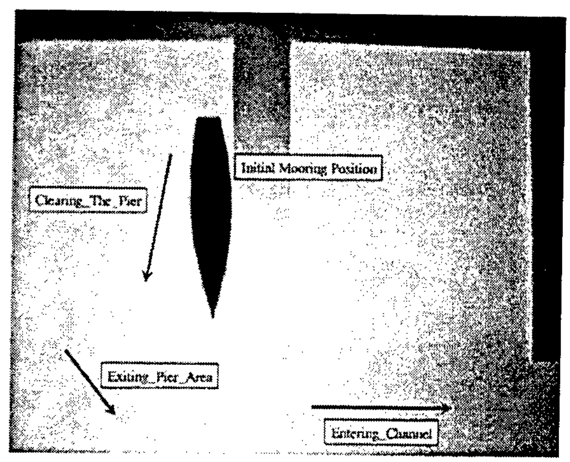

Figure 8. Initial mooring position on model.

3. Process of validation

The process of validating the two GOMS models for pier side ship-handling tasks, as discussed earlier was conducted in the similar manner as the Critical Decision Method for knowledge elicitation. The process consisted of three phases: 1) scenario familiarization, 2) initial task recount by participant, 3) probe questioning, and 4) model review and validation.

Out in the fleet, a conning officer is never expected to be able to conduct a successful pier side evolution right on the spot. Time is needed for him to evaluate the given situation and review in his mind the procedures and strategies he will use to properly accomplish the task. Therefore, since the participants were to assume the role of a conning officer, it was determined that they should be given all of the information about the scenario prior to their interview appointment. Thus, the first phase of the validation process entailed familiarizing the participant with the general task scenario.

The second and third phases were conducted during the initial interview session with the participant. The participant, with the aid of the pier model and any notes he may have brought along, commenced the second phase by first explaining how he would get the ship underway from the pier in accordance with the specified scenario. Once that task was complete, the participant was then asked to explain how he would safely moor the ship to the pier. As the participant explained how he would accomplish each task, the interviewer recorded the information by hand, on specially formatted sheets of paper (see Appendix B), and with the use of a miniature voice recorder. The interviewer allowed the participant to finish both tasks without interrupting, except to answer any questions the participant may have had. The third phase began after the participant completed the initial task review, where the interviewer would step through the phases of each task again and ask the participant to explain, in detail, the perceptual cues used during the particular phase and why they were used. This process not only allowed the interviewer to identify the cues used, but also to clarify any procedures that may have been unclear during the initial review. The initial interview process lasted approximately 45 minutes to 1 hour and was concluded once the interviewer felt there were no further questions for the participant. At this point the interviewer would then take the newly acquired information and try to format it so that it resembled as closely as possible to the GOMS model.

The final phase of the validation process consisted of the participant returning for another interview some time later to walk through both pier side evolutions once more. However, this time the participant and interviewer went through the tasks together and compared the differences, if any, between the information provided by the participant and the initial GOMS model. Any discrepancies found were thoroughly examined to determine if it was just a difference of opinion or a significant error in the GOMS model.

Throughout the entire validation process there was only one discrepancy that was considered significant enough to warrant changes to the GOMS model. The discrepancy was over the use of tugboats. The initial GOMS model was originally constructed under the assumption that no tugs would be available and that the conning officer would have to use only the ship in getting underway or mooring to a pier. Therefore, the initial GOMS model did not reflect any procedures concerning the use of tugboats. However, all of the participants opted to use tugboats. Thus, they all found that the model would not be accurate if it did not provide procedures for using a tug. In fact, all of the participants agreed that, due to the severe consequences of damaging the ship, it is very rare any type of pier side ship-handling would be conducted without the assistance of a tugboat. Therefore the model was changed to reflect using the assistance of a tugboat.

V. TASK ANALYSIS

A. GETTING UNDERWAY SAFELY FROM A PIER

The primary purpose of this thesis is to conduct a Cognitive Task Analysis of a Conning Officer performing pier side ship-handling evolutions. A GOMS model approach is used to construct the following detailed analysis of how a conning officer would get a ship underway from a pier. It is through the use of this analysis that the thesis focuses on the "science" part of ship handling. Additionally, since each ship type has its own specific ship handling characteristics, and every port has its own set of environmental attributes, every pier side ship-handling evolution is different. Therefore, one specific scenario has been chosen for this analysis. The scenario consists of a conning officer required to get a twin-screw ship underway from a pier under normal conditions, in which there are no other ships in the immediate vicinity and there is minimal wind or current acting on the vessel. Additionally, since the ship will have no bow thrusters available, a tugboat has been provided to assist in the evolution.

1. Unit Task Level Analysis

The Unit Task Level model shows that the primary goal is to get a ship underway from the pier. In order to accomplish this goal, each of the 5 subgoals must be completed. To make it easy to follow the GOMS model, the primary goal has been underlined with its 5 initial subgoals, or operators, made **bold**. Additionally, specific subgoals or methods have been *italicized* to indicate areas that have been provided supporting information through the use of Critical Cue Inventories.

goal: Get_A_Ship_Safely_Underway_From_Pier

- **goal: Complete_Brief_Phase (A)**
- **goal: Ensure_Ship_And_Crew_Is_Ready_To_Get_Underway (B)**
- **goal: Complete_Clearing_The_Pier (C)**
- **goal: Complete_Exiting_Pier_Area (D)**
- **goal: Complete_Entering_Channel_Phase (E)**

2. Functional Task Analysis

The Functional Level model continues to break down the subgoals of the Unit Task model even further by identifying more subgoals that must be achieved before higher level goals can be completed. The GOMS model used does not clearly account for the goals that must be repeated numerous times in order for the higher goal to be satisfied. Therefore, these recurring goals have been specifically identified to indicate that in some situations they may have to be repeated. For example, while getting a ship underway the conning officer will continually check specific areas to ensure he maintains a clear picture of the movement of the ship and its distance from the pier and other objects (i.e. neighboring ships).

goal: Get_A_Ship_Safely_Underway_From_Pier

. **goal: Complete_Brief_Phase (A)**

. . goal: Familiarize_Yourself_And_Watch_Team_Of_Underway_Plan

. . goal: Review Emergency Actions

. **goal: Ensure_Ship_And_Crew_Is_Ready_To_Get_Underway (B)**

. . goal: Complete_Underway_Check-Off_List

. . goal: Assess_Environmentals_And_Ship_Surroundings

. . goal: Visually_Assess_Ship's_Distance_To_Nearest_Obstructions

. goal: Complete_Clearing_The_Pier (C)

. . goal: Complete_Tie_Up_Of_Tug_In_Required_Position

. . goal: Receive_Order_From_CO_To_Get_Underway

. . goal: Complete_Singling_All_Lines

. . goal: Complete_Assessment_Of_Environmental_Effect_On_Ship

. . goal: Complete_Taking_In_All_Lines

. . goal: Swing_Stern_Away_From_Pier

. . goal: Swing_Bow_Away_From_Pier

. . goal: Complete_Assessment_Of_Ship's_Movement/Position

. . goal: Make_Adjustments

. . goal: Ensure_Distance_Between_ Ship_And_Pier_Increases

. goal: Complete_Exiting_Pier_Area (D)

. . goal: Ensure_Stern_Is_Clear_Of_Pier

. . goal: Ensure_Bow_Is_Clear_Of_Pier

. . goal: Position_Yourself_On_Centerline_Of_Ship

. . goal: Ensure_Bow_Direction_Matches_Heading_Of_Intended_Course

. . goal: Order tug to cease backing down

. . goal: Order engines ahead at a 2/3 bell

. . goal: Determine_Course_To_Steer

. . goal: Ensure_Bow_Direction_Matches_Heading_Of_Intended_Course

. . goal: Order tug to cease backing down

. . goal: Order_Helmsman_To_Steer_Determined_Course

. . goal: Assess_Response_Of_Ship

. . goal: Monitor_Intended_Course_For_Surface_Contacts

. goal: Complete_Entering_Channel_Phase (E)

. . goal: Complete_Casting_Off_Tug

. . goal: Complete_Port_Turn_Into_Channel

. . goal: Ensure_Ship_On_Correct_Heading

3. Detailed Level Task Analysis

The Detailed Level model further identifies subgoals that are needed to accomplish the subgoals of the Functional Level model. These subgoals include selections that the conning officer can choose from in order to accomplish that particular subgoal. As mentioned before, the purpose of this analysis is to provide a general sequence of goals in successfully getting a ship safely underway from the pier. Therefore, depending on the scenario, the conning officer may choose to select one method or a combination of several methods to achieve a particular goal.

Some tasks will be repeated many times throughout the evolution of getting the ship underway from a pier, therefore, the details of a task will appear only once in the analysis. For example, while the task to "Complete_Assessment_Of_Ship's _Movement/Position" appears repeatedly throughout the analysis, the details for that task will be explicitly stated only for its first occurrence. When the task again appears in the sequence it will simply be noted as "Complete_Assessment_of_Ship's_ Movement/Position" method.

The following detailed analysis and supporting narrative will describe all of the subgoals and methods needed to Get_A_Ship_Safely_Underway_From_Pier. Task Maps are placed at the beginning of each initial subgoal to make it easier for the reader to maintain his reference while reviewing the model.

goal: Get_A_Ship_Safely_Underway_From_Pier	
(A)	Complete_Brief_Phase
(B)	Ensure_Ship_And_Crew_Ready
(C)	Complete_Clearing_The_Pier
(D)	Complete_Exiting_Pier_Area
(E)	Complete_Entering_Channel_Phase

Figure 9. Task Map for Getting Underway.

goal: Get_A_Ship_Safely_Underway_From_Pier

. **goal: Complete_Brief_Phase (A)**

. . goal: Familiarize Yourself And Watch Team Of Underway Plan

. . . [select: Meet With CO and Discuss Strategy ...if CO requires

. . . Attend the Underway Brief ...usually required

. . . Go Over Intended Transiting Track with Navigator

. . . Present Your Intentions of Exiting Port at Underway Brief

. . . Receive Weather Information during Underway Brief

. . . goal: Receive Harbor Traffic Information

. . . . [select: Read projected traffic message

. . . Obtain from Operations Officer

. . . Call Harbor Authority via radio]

. . . goal: Receive Intended Engineering Plant Configuration

. . . . [select: Obtain from Chief Engineer at Underway Brief

. . . Talk with EOOW in Central Control]

. . goal: Review Emergency Actions

. . . [select: Discuss with fellow conning officers

. . . Read Commanding Officer's Standing Orders]]

As the above GOMS notation illustrates, the first subgoal that must be accomplished is the Complete_Brief_Phase. The purpose of this phase is to ensure that the conning officer and all of the other key personnel are thoroughly familiar with what is going to take place during the evolution. Generally, this familiarization process takes place during the underway brief, in which specific details pertaining to the event are disseminated to all of the ship's officers and key personnel in the officer's wardroom several hours before the actual event. The information presented during the brief includes the timeline of events, the expected engineering plant configuration, the projected weather, the expected shipping traffic, and a review of the actions that will be taken in the event there is an emergency or engineering casualty. In addition, the conning officer presents his plan on how he intends to maneuver the ship away from the pier and through the channel. The commanding officer will also offer his advice on what should take place and ensure that everyone is in concurrence on what will take place.

The underway brief, however, is only one portion of the familiarization phase for the conning officer. Although the conning officer will receive the majority of the operational information at the underway brief, it is up to him to solicit the ship handling characteristics from a great deal of other sources. The first of these sources is the ship's navigator. The navigator is the person in charge of maintaining all of the ship's charts and is the expert in the practice of studying wind, currents, and harbor charts. The navigator will usually go over the intended track and expected wind and currents with the conning officer. He will also provide additional advice on how the ship responds to certain situations. The conning officer will also speak to the ship's Chief Engineer, who will provide the conning officer with all of the necessary information pertaining to the ship's propulsion and steering systems. Another source of information for the conning officer is to speak with other conning officers. This offers a great deal of information because they will often speak of their experiences and give very good advice on particular situations that may arise.

Another good source of information is the ship's commanding officer. In fact, some commanding officers will require that the conning officer who will be "driving" the ship out, meet with him prior to the underway brief so that the two of them can discuss strategies in a one-on-one environment. The advantage of this is that it gives the conning officer a chance to present his intentions to the commanding officer prior to the underway brief, while at the same time gain some invaluable insight on the CO's own ship driving theories. In addition to meeting with the CO, the conning officer is also required to read the CO standing orders. The standing orders contain all of the CO's ideas on how everything must be run. It also explains in detail how to respond to casualties.

It is important to mention again that the brief phase is crucial to the success of the conning officer. The conning officer only begins to learn how to be a good ship handler when he fully understands what is going on around him.

The next subgoal that must be addressed is to ensure that the ship and crew is ready to get underway. The GOMS notation is as follows:

goal: Get_A_Ship_Safely_Underway_From_Pier	
(A)	Complete_Brief_Phase
(B)	Ensure_Ship_And_Crew_Ready
(C)	Complete_Clearing_The_Pier
(D)	Complete_Exiting_Pier_Area
(E)	Complete_Entering_Channel_Phase

Figure 10. Task Map for Getting Underway.

. **goal: Ensure_Ship_And_Crew_Is_Ready_To_Get_Underway_Phase (B)**

. . goal: Complete_Underway_Check-Off_List

. . . goal: Ensure_All_Required_Engines_Online

. . . . *goal: Verify_Engines_Are_Started_And_Online* (see Table 15)

. . . . [select: Receive report from EOOW (Engineering Officer of the Watch)

. . . . *Look at status board on bridge* ...if inside pilothouse

. . . . *Hear engines start up* ...if out on bridgewing

. . . . *See smoke come out of smoke stack* ...if out on bridgewing]

. . . goal: Conduct_Test_Of_Engine_Order_Telegraph

. . . . method: Follow procedures on PMS card

. . . goal: Ensure_All_Steering_Units_Are_Online_And_Operational

. . . . goal: Verify_Steering_Units_Are_Powered_Up

. . . . . method: Visually look to see if steering light is illuminated on helm

. . . goal: Start_Steering_Units ...if not already started

. . . . [select: Call after steering to start steering units

. . . . Call EOOW to have after steering start units]

. . . goal: Conduct_Rudder_Swing_Test

. . . . method: Follow procedures on PMS card

. . . goal: Ensure_All_Stations_Manned and Ready

. . . . method: Receive manned and ready reports from all stations

As mentioned earlier, the Ensure_The_Ship_And_Crew_Are_Ready phase is where the crew makes preparations to get the ship underway. The officer of the deck, with the assistance of the conning officer, verifies that the checklist's procedures are completed correctly as scheduled. One of the conning officer's roles is to ensure the ship's propulsion and steering systems are online and ready to respond to any order given. This also includes the electronic signaling devices that convert a verbal order by the conning officer into an electronic signal that is relayed to the engineering plant. The Engine Order Telegraph (EOT) is a circular dial that is divided into sectors for the respective engine speeds, such as ahead one-third or back two-thirds. When a verbal order is given to the lee helmsman, he turns a dial by hand that moves a pointer to the respective speed sector. This action causes the pointer in the engineroom to respond accordingly. Answering pointers on the telegraph indicate that the engineroom acknowledges the order. Testing the EOT ensures that engine room receives the correct engine order. In addition, the conning officer will conduct the "Rudder Swing Test", which verifies the rudder responds accurately to the signal given by the helmsman on the bridge.

. . . goal: Ensure_Anchor_Is_Ready_For_Letting_Go

. . . . [select: Receive ready report from 1st LT

. . . .   Visually observe anchor status on forecastle]

. . . goal: Ensure_All_Service_Lines_Are_Disconnected

. . . . [select: Receive ready report from EOOW

. . . .   Visually observe status from bridge wing]

. . . goal: Ensure_Brow_Has_Been_Removed

. . . . [select: Receive report from quarterdeck via radio

. . . .   Visually observe status from bridge wing]

In addition to ensuring the propulsion and steering systems operate properly, the conning officer will also verify that preparations are being made to the anchor. Although the ships deck officer or 1st Lieutenant will normally notify the bridge when the anchor is ready, the conning can also visually observe the anchor being "walked out" to the water edge and set for an immediate release. The anchor must be able to be dropped in a moments notice in the event the ship loses propulsion due to a casualty. By dropping the anchor, the ship would be prevented from drifting into any neighboring hazards, such as shoal water or other ships.

. . . goal: Establish Communications

. . . . [select: Test Sound Powered Hand Set with Helmsman/Lee helmsman

. . . . Test Voice Tube

. . . . Identify and Position Voice Relay Person

. . . . Conduct_Radio_Check_With_Bow/Stern_Watches

. . . . Conduct sound powered phone check with all stations

. . . . Conduct Bridge to Bridge Communication with Harbor Control

. . . . Test Casualty Alarms

. . . . Test Ship's Whistle]

During pier side evolutions, the conning officer must be able to communicate with not only the helmsman and lee helmsman, but with all of the line handling stations, assisting tug boats, and other vessels in the vicinity. It is imperative that communications between the conning officer and these other stations are always maintained. Therefore, it is the conning officer's responsibility to ensure that all of these means of communications are established, tested, and ready for use.

. . . goal: Receive_Permission_To_Get_Underway_From_Harbor_Control

. . . . method: Call Harbor Control on Bridge to Bridge radio

. . . goal: Ensure_Tug_Boats_Are_Standing_By ...if tugs are used

. . . . method: Visually observe tugs positioned next to ship

. . . goal: Ensure_Harbor_Pilot_Onboard

. . . . [select: Visually look in pilot house

. . . .   Hear pilot announced on bridge]

Prior to getting underway, the ship, according to harbor regulations, must request permission to get underway from the pier. Calling the harbor control station not only gives permission for the ship to get underway, but it also provides detail to the ship's bridge team as to the name of the pilot that will be boarding them and what his arrival time will be. Many ships have been delayed in their departure due to the late arrival of the pilot and the assisting tugboats.

. . *goal: Assess_Environmentals_And_Ship_Surroundings* (see Table 2)

. . . goal: Position_Yourself_On_Bridgewing

. . . . [select: Port side Bridge wing ...if moored on port side

. . . . Starboard Bridge wing ...if moored on starboard side]

. . . goal: Determine_Wind_Direction_And_Speed

. . . . [select: Take reading from anonometer

. . . . *Visually observe direction wind bird is pointing*

. . . . *Visually observe direction ships flags/pennants are blowing*

. . . . *Visually observe direction of wind generated wakes on water*]

. . . goal: Determine_Current

. . . . [select: *Visually observe wake in water about pier pilings*

. . . . *Visually observe direction fenders tend in water*

. . . . *Visually observe wake in water about channel buoy*

. . . . *Visually observe direction and rate of speed of floating objects*

. . . . Look at tide and current charts]

. . *goal: Assess_Ship's_Distance_To_Nearest_Obstructions* (see Table 3)

. . . *goal: Determine_Distance_Between_Bow_And_Closest_Obstruction*

. . . . [select: Visually judge distance

. . . . Use distance reported by surface radar

. . . . Receive estimated distance from bow watch

. . . . Confer with commanding officer, pilot, or OOD]

. . . *goal: Determine_Distance_Between_Stern_And_Closest_Obstruction*

. . . . [select: Visually judge distance

. . . . Receive estimated distance from stern watch

. . . . Use distance reported by radar surface

. . . . Confer with commanding officer, pilot, or OOD]

. . . *goal: Determine_Distance_Between_Beam_And_Closest_Obstruction*

. . . . [select: Visually judge distance

. . . . Check distance reported by radar

. . . . Confer with commanding officer, pilot, or OOD]

With the conning officer positioned on the bridgewing, he begins to make a mental picture of situation by identifying pertinent visually cues. By walking to both sides of the ship and viewing the surrounding area, the conning officer not only gains visual references to neighboring ships, but he is also able to asses the environmental effects. The conning officer has the ability to verify the accuracy of his visual assessment on distances in a variety of ways. One way is to ask the officers stationed on the bow and stern to visually estimate the distances from their vantage point. Another way is to use radar, like the commercial FURUNO radar, to get estimate distances to potential obstructions. Again, it is important for the conning officer to accumulate as much information as possible so that he maintains a detailed picture of what is taking place around the ship.

goal: Get_A_Ship_Safely_Underway_From_Pier	
(A)	Complete_Brief_Phase
(B)	Ensure_Ship_And_Crew_Ready
(C)	Complete_Clearing_The_Pier
(D)	Complete_Exiting_Pier_Area
(E)	Complete_Entering_Channel_Phase

Figure 11. Task Map for Getting Underway.

. **goal: Complete_Clearing_The_Pier (C)**

. . goal: Complete_Tie_Up_Of_Tug_In_Required_Position

. . . [select: Order tug off port bow ...if Starboard side moor

. . . Order tug off starboard bow ...if Port moor side moor

. . goal: Receive_Order_From_CO_To_Get_Underway

. . . method: Verbal message from CO

By the time the OOD reports to the commanding officer that the "Getting Underway Checklist" is complete and that the ship is ready to get underway, the commanding officer, conning officer, and pilot have all briefly discussed the strategy they plan to use in getting underway. The pilot has also briefed them on the latest information concerning shipping traffic they might encounter on their transit as well as any changes to winds or currents. With the tugboat positioned off the ship's starboard bow and the ship ready to get underway, the commanding officer will tell the conning officer he has permission to get the ship underway.

. . goal: Complete_Singling_All_Lines

. . . goal: Pass_Order_To_Single_Up_All_Lines

. . . . [select: Verbally pass to S/P talker

. . . . Verbally pass via hand held radio]

. . . *goal: Verify_All_Lines_Singled_Up* (see Table 4)

. . . . [select: Receive report from S/P Talker

. . . . *Visually observe lines singled up*

. . . . Receive report from line handling stations via hand held radio]

. . goal: Complete_Assessment_Of_Environmental_Effect_On_Ship

. . . *goal: Visually_Check_State_Of_Mooring_Lines* (see Table5)

. . . . [select: *Visually observe any significant strain on mooring lines*

. . . . *Visually observe any significant slack on mooring lines*]

Being positioned on the port bridge wing, the conning officer has the best vantage point to observe everything taking place along the pier. He is able to look up and down the port side of the ship as the lines are being "singled-up" and visually check for any noticeable changes in the ship's position with the pier. Any significant change in the tension of the mooring lines is the first indication of environmental forces acting on the ship.

Before the commanding officer gives the order to the conning officer to "take in all lines" he must be comfortable with the developing situation. Any dramatic change in the wind or current observed after the lines are singled can cause a re-evaluation of their strategy in getting the ship underway. Since the remaining procedures of the task analysis are scenario dependent, it will be assumed that the initial environmental assessment showed no change in the expected status of the wind or current.

. . goal: Complete_Taking_In_All_Lines

. . . goal: Receive_Order_From_CO_To_Take_In_All_Lines

. . . . method: Verbal message

. . . goal: Give_Order_To_Take_In_All_Lines

. . . . [select: Verbally pass to S/P talker

. . . .   Verbally pass via hand held radio]

. . . *goal: Verify_All_Lines_Cast_Off_From_Pier* (see Table 4)

. . . . [select: *Visually observe lines cast off*

. . . .   Receive report from line handling stations via S/P talker

. . . .   Receive report from line handling stations via hand held radio]

Under certain circumstances, when the order is given to "cast off all lines" it may be necessary to leave one of the spring lines secured to the pier. This technique allows the ship to swing its stern away from the pier without moving forward. However, with the assumption that there are no neighboring ships directly in front the conning officer is able to remove all mooring lines at the same time.

With all lines cast from the pier by the assisting line handlers on the pier, the conning officer will then use the ship's engines and rudders to swing the stern away from the pier. Generally, the conning officer will, first, order a full rudder in the direction towards the pier. Next, he will order his outboard engine "ahead two-thirds." By placing the rudder over before giving an engine order allows for a greater thrust of water flow to act the deflected rudder. This action is known as "kicking out" the stern away from the pier. After giving these orders, the conning officer observes the response of the ship by visually watching the space between the pier and the stern. If after a few moments there is no noticeable change, or if the stern begins to swing in towards the pier, the conning officer will make adjustments to his engines by either increasing the speed or using the inboard engine.

. . goal: Swing_Stern_Away_From_Pier

. . . goal: Issue_Rudder_Order ...to helmsman

. . . . goal: Determine_Direction_Of_Rudder

. . . . . [select: Use Left Rudder ...if moored on port side of ship

. . . . . Use Right Rudder ...if moored on starboard side of ship]

. . . . goal: Determine_Amount_Of_Rudder ...Depending on situation

. . . . . [select: Desired Degrees Of Rudder] ...15 degrees of rudder angle

. . . . goal: Give_Verbal_Order_To_Helm

. . . . goal: Receive_Repeating_Of_Order_From_Helmsman

. . . . . [select: Acknowledge Repeat Back ...if order properly understood

. . . . . Repeat Order ...if order not properly acknowledged]

. . . . goal: Determine_If_Order_Was_Executed

. . . . . [select: Observe Rudder Angle Indicator]

. . . . . goal: Receive_Report_That_Order_Was_Executed_From_Helsman

. . . . . . [select: Acknowledge Execution ...if properly executed

. . . . . . Repeat Order ...if not properly executed]

. . . goal: Issue_Engine_Order ...to lee helmsman

. . . . goal: Determine_Engine_To_Use

. . . . . [select: Port Engine ...to affect port screw

. . . . . Starboard Engine ...to affect starboard screw]

. . . . goal: Determine_Direction_Of_Engine

. . . . . [select: Use Ahead Bell ...if forward motion is desired

. . . . . Use Backing Bell ...if reversing motion is desired

. . . . . Use Combination ...if twisting motion is desired]

. . . . goal: Determine_Desired_Speed

. . . . . [select: Use 1/3 Bell ...if rpm for 5 knots needed

. . . . . Use 2/3 Bell ...if rpm for 10 knots needed

. . . . . Use Standard Bell ...if rpm for 15 knots needed

. . . . . Use Full Bell ...if rpm for 20 knots needed

. . . . . Use Flank Bell ...if rpm for 25 knots/Not for backing bell

. . . . . Stop ...all throttles closed]

. . . . goal: Give_Verbal_Order_To_Lee_Helmsman

. . . . . [select: Use Sound Powered Handset

. . . . . Use Sound Tube ...if handset does not work

. . . . . Give order to relay person ...if previous methods fail]

. . . . goal: Receive_Repeating_Of_Order_From_Lee_Helmsman

. . . . . [select: Acknowledge Repeat Back ...if order properly understood

. . . . . Repeat Order ...if order not properly acknowledged]

. . . . *goal: Determine_If_Engine_Order_Was_Executed* (see Table 6)

. . . . . [select: *Observe Churning Of Water At Stern*

. . . . . *Hear bell of EOT acknowledgment*

. . . . . *Observe Sound Of Engines Accelerating*

. . . . . *Observe Plume of Smoke Coming Out Of Smoke Stack*]

. . . . . goal: Receive_Execution_Of_Order_From_Lee Helmsman

. . . . . . [select: Acknowledge Report ...if properly executed

. . . . . . Repeat Order ...if not properly executed]

As the stern begins to swing away from the pier, the tendency is for the bow to be swung back into the pier. Therefore, the conning officer orders the tugboat to commence backing out which forces the bow to move away from the pier as soon as he notices the stern begin to swing out. Ultimately, the conning officer wants the bow and stern to move away from the pier at the same rate, resulting in the ship to move out parallel to the pier.

. . goal: Swing_Bow_Away_From_Pier

. . . goal: Order tug to use 1/3 backing bell

. . . . [select: Verbally pass to tug via hand held radio ...if controlling tugs

. . . . Verbally relay order through pilot] ...if pilot controlling tugs

. . *goal: Complete_Assessment_Of_Ship's_Movement/Position* (see Table 8)

. . . goal: Determine_Motion_Of_Ship

. . . . [select: *Visually Observe Change In Separation Between Ship And Pier*

. . . . *Visually Observe Swing of Stern*

. . . . *Visually Observe Swing of Bow*]

. . . goal: Monitor_Distance_Opening/Closing_Rate

. . . . [select: goal: *Visually Observe Separation Between Ship And Pier*

. . . . . method: *Visually watch ship, at waterline, move away from pier*

. . . .   Request Distances From Bow/Stern Watches]

. . . goal: *Determine_Forward/Aft_Movement_Of_Ship* (see Table 8)

. . . . [select: *Compare Your Position With Fixed Object On Pier*

. . . .   Receive change in distance from Bow/Stern Watches]

. . goal: Make_Adjustments   ...if situation requires

As the ship begins to move away from the pier, the conning officer monitors a fixed point on the pier. The relative motion of this fixed point will indicate the direction and magnitude of the ship's forward or aft motion. For example, if the point appears to visually drift aft, it is an indication that the ship is moving forward. Usually, the conning officer tries to minimize any forward or aft motion until there is no possibility of the ship hitting the pier with its stern or its bow colliding with a ship directly in front.

. . . goal: Adjust_Ship's_Forward_Motion   ...if forward motion not desired

. . . . goal: Stop_Ahead_Engine

. . . . . [select: Port Engine   ...if in a starboard twist

. . . . .   Starboard Engine   ...if in a port twist]

. . . goal: Adjust_Ship's_Aft_Motion   ...if aft motion not desired

. . . . goal: Stop_Backing_Engine

. . . . . [select: Port Engine   ...if in a port twist

. . . . .   Starboard Engine   ...if in a starboard twist]

As the conning officer observes the ship's response to his initial setting of the engines and rudder, he may determine that the motion of the bow or stern is not what he may be expecting. For instance, if the stern begins to swing out away from the pier too quickly, it may cause the bow to go back into the pier. Therefore, the conning officer must make adjustments to his engines in order to maintain control of the ship's movement.

. . . goal: Adjust_Rate_Of_Swing_Of_Bow

. . . . goal: Increase_Rate_Of_Swing ...if need to increase is determined

. . . . . [select: Increase RPM on outboard engine

. . . . . Increase RPM on inboard engine

. . . . . Order tug to increase backing RPM

. . . . . Increase RPM on both engines]

. . . . goal: Decrease_Rate_Of_Swing ...if need to decrease is determined

. . . . . [select: Decrease RPM on outboard engine

. . . . . Decrease RPM on inboard engine

. . . . . Order tug to decrease backing RPM

. . . . . Order tug to push using ahead RPM]

. . . goal: Adjust_Rate_Of_Swing_Of_Stern

. . . . goal: Increase_Rate_Of_Swing

. . . . . [select: Increase RPM on outboard engine

. . . . . Increase RPM on inboard engine

. . . . . Increase RPM on both engines]

. . . . goal: Decrease_Rate_Of_Swing

. . . . . [select: Decrease RPM on outboard engine

. . . . . Decrease RPM on inboard engine

. . . . . Decrease amount of rudder being used]

Judging the distance between the ship and the pier takes experience and is often difficult to approximate. On larger vessels, the conning officer's position is so far away from the stern or bow it is very hard to get an accurate distance. However, there is always an officer on the bow and stern who assists the conning officer by providing estimate distances to the pier.

. . goal: Ensure_Distance_Between_ Ship_And_Pier_Increases

. . . *goal: Measure_Distance_Between_Entire_Ship_And_Pier* (see Table 9)

. . . . *goal: Measure_Distance_Between_Stern_And_Pier*

. . . . . [select: Look at space between stern and pier and judge distance

. . . . . Query stern watch for distance report]

. . . . *goal: Measure_Distance_Between_Amidships_And_Pier*

. . . . . method: Look at space between amidships and pier and judge distance

. . . . *goal: Measure_Distance_Between_Bow_And_Pier*

. . . . . [select: Look at space between bow and pier and approximate distance

. . . . . Query bow watch for distance report]

Generally, once the ship is 25 to 50 feet away from the pier, it can safely be maneuvered without the risk of its stern hitting the pier. At this point, the conning officer must determine the ship's relative position with the pier and surrounding vessels by making visual observations of the bow and stern. Only when he is comfortable with the ship's position, will he begin to maneuver the ship away from the pier and out towards the channel.

goal: Get_A_Ship_Safely_Underway_From_Pier	
(A)	Complete_Brief_Phase
(B)	Ensure_Ship_And_Crew_Ready
(C)	Complete_Clearing_The_Pier
(D)	Complete_Exiting_Pier_Area
(E)	Complete_Entering_Channel_Phase

Figure 12. Task Map for Getting Underway.

. goal: Complete_Exiting_Pier_Area (D)

. . goal: Ensure_Stern_Is_Clear_Of_Pier

. . . *goal: Measure_Distance_Between_Stern_And_Pier* ...same as before

. . . *goal: Determine_Distance_Between_Stern_And_Closest_Obstruction*

. . . . [select: *Visually judge distance*

. . . . Receive estimated distance from stern watch

. . . . Use distance reported by surface radar

. . . . Confer with commanding officer, pilot, or OOD]

. . goal: Ensure_Bow_Is_Clear_Of_Pier

. . . *goal: Measure_Distance_Between_Bow_And_Pier* ...same as before

. . . *goal: Determine_Distance_Between_Bow_And_Closest_Obstruction*

. . . . [select: *Visually judge distance*

. . . . Use distance reported by surface radar

. . . . Receive estimated distance from bow watch

. . . . Confer with commanding officer, pilot, or OOD]

As the conning officer begins to maneuver the ship out of the pier he will move inside the bridge and position himself on the centerline of the ship. The centerline, usually marked by a gyrocompass repeater that allows the conning officer to check the ship's heading, provides the optimal vantage point for the conning officer to conduct the remainder of the evolution from. From this position, the conning officer maneuvers the ship so that its bow points out towards a predetermined heading.

The heading usually corresponds to a fixed marker located ahead of the ship at a considerable distance. These markers, usually defined by the pilot, can be anything that allows the conning officer to physically align the bow to it. For example, ships departing from the Pearl Harbor Naval Station will sometimes align their bow to the left side of an old armory building when they exit the pier area. Additionally, a long pole mounted on the bow of the ship, known as the jack staff, aids the conning officer in aligning the bow with the fixed marker.

. . goal: Position_Yourself_On_Centerline_Of_Ship

. . . method: Enter pilot house and stand in center of it

. . goal: Determine_Course_To_Steer

. . . [select: Use bearing to fixed marker

. . .   Use navigator's recommended course

. . .   Use CO's/pilots recommended course]

. . goal: Ensure_Bow_Direction_Matches_Heading_Of_Intended_Course

. . . goal: Verify_Current_Position_Of_Bow

. . . . [select: Compare gyrocompass heading with intended heading

. . . .   Align bow with predetermined object in front of ship]

. . . goal: Make_Necessary_Adjustments_To_Bow_Position   ...if necessary

. . . . [select: Order tug to continue backing down

. . . .   Order tug to cease backing down

. . . .   Issue engine orders

. . . .   Issue rudder orders]

. . goal: Order tug to cease backing down

. . . [select: Issue order via hand held radio

. . .   Relay order through pilot]

Once the ship is properly positioned so that it can begin to safely move forward out towards the channel, the conning officer will order both engines ahead and give a course for the helmsman to steer. The conning officer taking a bearing of the fixed marker determines this course. Taking a bearing of an object is very simple and quick to do. Sitting on top of the gyrocompass is an alidade, similar to a small telescope that can swivel around 360 degrees, which allows the conning officer by looking through its eyepiece to align the landmark or buoy with a thin vertical line. Once the fixed marker is aligned with the line, the conning officer can then look down onto the gyrocompass and read the bearing in degrees that the marker lies from the ship.

. . goal: Order engines ahead at a 2/3 bell

. . . method: Issue engine orders to lee helm   ...same method as before

. . goal: Order_Helmsman_To_Steer_Determined_Course

. . . method: Issue rudder orders to helmsman   ...same method as before

As the ship begins to move forward, it is imperative that the conning officer continually monitor the ship's response and its position as it slowly progresses out of the pier area. Although the ship's navigator will provide the conning officer position reports every minute, these reports only reflect where the ship was. Therefore, the conning officer must use visual cues to determine the ship's position. He can also estimate the ship's speed through the water by observing the rate at which the pier and other fixed objects pass down the side of the ship.

. . *goal: Assess_Response_Of_Ship* (see Table 7)

. . . goal: Determine_Motion_Of_Ship

. . . . method: *Visually compare ship's position with fixed object on pier*

. . . goal: Monitor_Ship's_Change_In_Speed

. . . . [select: *Look at speed indicator*

. . . . *Visually compare ships position with fixed object on pier*

. . . . Ask navigator for ship's speed over ground]

. . *goal: Monitor_Intended_Course_For_Surface_Contacts* (see Table 10)

. . . [select: *Visually look forward of ship for other ships or small water craft*

. . . Request contact report from surface radar operator

. . . Confer with OOD]

Often times, as the ship exits a pier area it must make a dramatic turn past the end of the pier to enter the channel. For the scenario used in this task analysis, the ship must make a 90 degree port, or left, turn out of the pier are and into the channel. The rule of thumb in making this turn is to commence the turn only after the pivot point of the ship is past the end, or head, of the pier. Although the ship's navigation team also provides a recommendation on when to start the turn, a prudent conning officer must always visually verify that their recommendation is correct.

As the ship exits the protected pier area, it can sometimes experience a strong change in the current as it enters the channel. For example, ships that departed from the former Alameda Naval Station near San Francisco, experienced a channel current that would often times be up to 3 knots. As soon as the ships entered the channel, the current would force the bow to begin to drift either left or right. This then forced the conning officer to make drastic rudder or engine adjustments to prevent the ship from being forced into the neighboring shoal water. Under normal conditions, the tugboat is usually ordered to cast off prior to the ship making its turn. However, in the event that the turn is very tight or if there is a strong current in the channel that could dramatically effect the turning performance of the ship, a tugboat may be used to assist in the turn.

goal: Get_A_Ship_Safely_Underway_From_Pier	
(A)	Complete_Brief_Phase
(B)	Ensure_Ship_And_Crew_Ready
(C)	Complete_Clearing_The_Pier
(D)	Complete_Exiting_Pier_Area
(E)	Complete_Entering_Channel_Phase

Figure 13. Task Map for Getting Underway.

. **goal: Complete_Entering_Channel_Phase (E)**

. . goal: Complete_Casting_Off_Tug ...depending on situation

. . . method: Order tug to cast off

. . goal: Complete_Port_Turn_Into_Channel

. . . *goal: Determine_When_To_Commence_Turn* (see Table 11)

. . . . [select: *Assess environmentals acting on ship*

. . . . Confer with Pilot/CO

. . . . Acknowledge turn recommendation from navigator]

. . . goal: Determine_Position_Of_Ship

. . . . [select: *Measure distance between ship and the pier* (see Table 9)

. . . . Receive position report from navigator

. . . . Confer with Pilot/CO]

During restricted maneuvering situations, the conning officer does not have enough time or room to make any type of course change without having a thorough plan of action. Therefore, prior to commencing the port turn, the conning officer must know exactly how he is going to make the turn and what course he intends to steer once he finishes the turn. Of course, all of these decisions are dependent on the given situation. For example, the faster the ship is moving through the water, the less amount of rudder angle is needed to complete the turn. However, the faster the turn is made, the less time the conning officer has to steady on the given course.

Generally, the course that will be steered once the turn is completed has been provided to the conning officer by the navigator. Through intense planning, the navigation team generates a complete list of all of the required turns needed for the out bound transit, including the turn out of the pier area. However, there are times when this course is not sufficient and the conning officer must use other methods of determining a course.

This particular scenario requires the conning officer to make a left turn out of the pier area. However, the following subgoals and methods that represent the procedures utilized by the conning officer to make this turn are similarly used if the situation called for a right turn. The only difference being that the subgoal would be to "Commence_Right_Turn."

. . . goal: Commence_Port_Turn

. . . . goal: Ensure_Ship's_Pivot_Point_Past_End_Of_Pier

. . . . . [select: Visually measure ship's position in relation to end of pier

. . . . . Request stern watch to notify when stern past end of pier]

. . . . goal: Clear_Port_Side_Of_Ship

. . . . . method: Walk to port bridge wing and visually check for contacts

. . . . goal: Order_Left_Rudder

. . . . . method: Issue rudder order to helmsman

. . . . goal: Determine_Course_To_Come_To

. . . . . [select: Course of first leg of outbound transit ...scenario dependent

. . . . . Bearing to first channel marker ...scenario dependent

. . . . . Navigation team's recommended course ...scenario dependent

. . . . . CO/Pilot's recommended course ...scenario dependent]

. . . . goal: Order_Course_To_Steer ...once course determined

. . . . . method: Verbally tell helmsman course to steady on

. . . *goal: Assess_Ship's_Response* (see Table 7)

As the ship makes its turn, the conning officer observes the turn and ensures that the ship clears the end of the pier and steadies on the correct heading. Although there is usually a very experienced person manning the helm, the conning officer must closely monitor the way the turn is carried out and be ready to make adjustments should the helmsman fail to steady the ship in time or steady on the wrong course.

. . goal: Ensure_Ship_On_Correct_Heading

. . . [select: Look at ship's gyrocompass and compare with intended course

. . . Receive position report from navigator

. . .   Confer with Pilot/CO]

. . goal: Make_Necessary_Course_Adjustments

. . . method: Issue rudder orders

As soon as the ship becomes successfully positioned on the required course to commence the first leg of the harbor transit, the conning officer accomplishes the primary goal of getting the ship safely underway from the pier and transitions into the next critical event, which is navigating through the harbor channel.

B. MOOR SHIP SAFELY TO A PIER

The following task analysis is of a conning officer performing a mooring evolution, in which a twin screw ship is maneuvered in from the harbor channel to a berth on a pier. The situation, as defined earlier, calls for the conning officer to moor the ship to the pier "bow in and starboard side to."

1. Unit Task Analysis

The Unit Task Level model shows that the primary goal is to safely moor a ship alongside a pier. In order to accomplish this goal, each of the 7 subgoals must be completed. To make it easy to follow the GOMS model, the primary goal has been <u>underlined</u> with its 7 initial subgoals, or operators, made **bold**. Additionally, specific subgoals or methods have been *italicized* to indicate areas that have been provided supporting information through the use of Critical Cue Inventories.

<u>goal: Safely_Moor_A_Ship_Alongside_A_Pier</u>

. **goal: Complete_Brief_Phase (F)**

. **goal: Complete_Entering_Port_Checklist (G)**

. **goal: Enter_Pier_Area (H)**

. **goal: Complete_Pier_Approach_Phase (I)**

. **goal: Complete_Positioning_and_Stopping (J)**

. **goal: Complete_Maneuvering_Ship_Against_Pier_Phase (K)**

. **goal: Complete_Doubling_Lines_Phase (L)**

2. Functional Task Analysis

Similar to the Functional Level in the "Getting Underway from a Pier" task analysis, this Functional Level model continues to break down the tasks a conning officer must generally accomplish while mooring a ship to a pier.

goal: Safely_Moor_A_Ship_Alongside_A_Pier

. **goal: Complete_Brief_Phase (F)**

. . goal: Familiarize_Yourself_And_Watch_Team_Of_Entering_Port_Plan

. **goal: Ensure_Ship_And_Crew_Is_Ready_To_Enter_Port (G)**

. . goal: Complete_Entering_Port_Check-Off_List

. **goal: Enter_Pier_Area (H)**

. . goal: Safely_Complete_Harbor_Transit

. . goal: Reduce_Ship's_Speed

. . goal: Verify_Pier_Status_Agrees_With_What_Was_Previously_Briefed

. **goal: Complete_Pier_Approach_Phase (I)**

. . goal: Maneuver_Ship_So_It_Has_Proper_Approach_Angle_With_Pier

. . goal: Assess_Environmentals_And_Ship_Surroundings

. . goal: Visually_Assess_Ship's_Distance_To_Nearest_Obstructions

. . goal: Complete_Assessment_Of_Ship's_Movement/Position

. . goal: Reduce_Ship's_Speed_To_Bare_Steerage_Way

. . goal: Assess_Environmentals_And_Ship_Surroundings

. **goal: Complete_Positioning_and_Stopping (J)**

. . goal: Order_Tug_To_Tie_Itself_Up_To_Ship's_Port_Bow

. . goal: Approach_Within_25-50_Feet_Of_Pier

. . goal: Maneuver_Ship_So_Mooring_Side_Is_Parallel_To_Pier

. . goal: Stop_Headway_Of_Ship

. . goal: Send_Over_All_Lines

. **goal: Complete_Maneuvering_Ship_Against_Pier_Phase (K)**

. . goal: Verify_Ship_Properly_Aligned_With_Pier

. . goal: Monitor_Ship's_Position_And_Distance_From_Pier

. . goal: Make_Adjustments_To_Ship's_Position

. . goal: Verify_All_Lines_Passed

. . goal: Move_Ship_In_Against_Pier

. . goal: Monitor_Ship's_Position_And_Distance_From_Pier

. . goal: Make_Adjustments_To_Ship's_Position

. . goal: Verify_Ship_Properly_Against_Pier

. **goal: Complete_Doubling_Lines_Phase (L)**

. . goal: Ensure_Ship_Maintains_Proper_Alignment_With_Pier

. . goal: Order_All_Lines_Singled_Up

. . goal: Ensure_Mooring_Lines_Properly_Maintain_Ship's_Position

. . goal: Issue_Order_To_Double_Up_All_Lines

. . goal: Ensure_All_Lines_Doubled_Up

3. Detailed Task Analysis

As before, further decomposing the subgoals, or operators develops the Detailed Level model, identified in the Functional Level model. Amplifying documentation has been added to provide the reader with additional information on the subgoals or methods being accomplished by the conning officer.

Like getting a ship underway, mooring a ship to a pier takes the same amount of preparation prior to conducting the evolution. In fact, the procedures a conning officer uses in acquiring the prerequisite knowledge to successfully moor to a pier are the same as they are for getting underway. The only difference is that the conning officer returning to port does not have the advantage of assessing the environmental conditions prior to conducting the evolution. His first personal assessment comes only after the ship has arrived to the pier area. Therefore, during mooring evolutions, the conning officer is heavily dependent on the weather information disseminated during the Entering Port brief as well as the information provided by the harbor pilot once he comes onboard.

Goal: Safely Moor A Ship Alongside A _Pier	
(F)	Complete_Brief_Phase
(G)	Ensure_Ship_And_Crew_Ready
(H)	Enter_Pier_Area
(I)	Complete_Pier_Approach_Phase
(J)	Complete_Positioning_And_Stopping
(K)	Complete_Maneuver_Ship_Against_Pier
(L)	Complete_Doubling_Lines_Phase

Figure 14. Task Map for Mooring.

goal: Safely_Moor_A_Ship_Alongside_A_Pier

. **goal: Complete_Brief_Phase (F)**

. . goal: Familiarize_Yourself_And_Watch_Team_Of_Entering_Port_Plan

. . . [select: Meet With CO and Discuss Strategy

. . . Attend the Entering Port Brief

. . . Go Over Intended Transiting Track with Navigator

. . . Present Your Intentions of Mooring at Entering Port Brief

. . . Receive Weather Information during Entering Port Brief

. . . goal: Receive Harbor Traffic Information

. . . . [select: Read projected traffic message

. . . Obtain from Operations Officer

. . . Call Harbor Authority via radio]

. . . goal: Receive_Intended_Engineering_Plant_Configuration

. . . . [select: Obtain from Chief Engineer at Underway Brief

. . . Talk with EOOW in Central Control]

. . goal: Review_Emergency_Actions

. . . [select: Discuss with fellow conning officers

. . . Read Commanding Officer's Standing Orders]

While underway, the ship establishes the normal at sea watch rotation. Therefore, between one half hour and an hour before the ship approaches the entrance of the channel, the ship will man all of the Sea and Anchor Detail stations and finalize the entering port preparations. The current bridge watch team is usually relieved at this time by the team that will take the ship into port.

Goal: Safely Moor A Ship Alongside A _Pier	
(F)	Complete_Brief_Phase
(G)	Ensure_Ship_And_Crew_Ready
(H)	Enter_Pier_Area
(I)	Complete_Pier_Approach_Phase
(J)	Complete_Positioning_And_Stopping
(K)	Complete_Maneuver_Ship_Against_Pier
(L)	Complete_Doubling_Lines_Phase

Figure 14. Task Map for Mooring.

. goal: Ensure_Ship_And_Crew_Is_Ready_To_Enter_Port (G)

. . goal: Complete_Entering_Port_Check-Off_List

. . . goal: Ensure_All_Required_Engines_Online

. . . . goal: *Verify_Engines_Are_Started_And_Online* (see Table 15)

. . . . [select: Receive report from EOOW (Engineering Officer of the Watch)

. . . . *Look at status board on bridge*

. . . . *See additional black smoke come out of smoke stack*]

. . . goal: Conduct_Test_Of_Engine_Order_Telegraph

. . . . method: Follow procedures on PMS card

. . . goal: Ensure_All_Steering_Units_Are_Online_And_Operational

. . . . goal: Verify_Steering_Units_Are_Powered_Up

. . . . . method: Visually look to see if steering light is illuminated on helm

. . . goal: Start_Stand_By_Steering_Units ...if not already started

. . . . [select: Call after steering to start steering units

. . . . Call EOOW to have after steering start units]

. . . goal: Conduct_Rudder_Swing_Test ...if not already completed

. . . . method: Follow procedures on PMS card

. . . goal: Ensure_All_Stations_Manned and Ready

. . . . method: Receive manned and ready reports from all stations

. . . goal: Ensure_Anchor_Is_Ready_For_Letting_Go

. . . . [select: Receive ready report from 1st LT

. . . . Visually observe anchor status on forecastle]

. . . goal: Establish Communications

. . . . [select: Test Sound Powered Hand Set with Helmsman/Lee helmsman

. . . . Test Voice Tube

. . . . Identify and Position Voice Relay Person

. . . . Conduct Radio Check With Bow/Stern Watches

. . . . Conduct sound powered phone check with all stations

. . . . Conduct Bridge to Bridge Communication with Harbor Control

. . . . Test Casualty Alarms

. . . . Test Ship's Whistle]

. . . goal: Receive_Permission_To_Enter_Port_From_Harbor_Control

. . . . method: Call Harbor Control on Bridge to Bridge radio

The call to the Harbor Control station not only gives the ship permission to enter the channel, but also informs the bridge team where they will be picking up the pilot. Unlike when a ship gets underway from the pier, the pilot is picked up either prior to or immediately after the ship transits the harbor channel.

. . . goal: Ensure_Tug_Boats_Are_Standing_By ...if tugs are used

. . . . method: Visually observe tugs positioned next to ship

. . . goal: Ensure_Harbor_Pilot_Onboard

. . . . [select: Visually look in pilot house for pilot

. . . . Hear pilot announced on bridge]

As the ship approaches the pier area, the conning officer gets his first chance to visually assess the designated pier area. He will look for any type of changes to the pier area that conflict with information during the briefing phase. For example, a conning officer may be briefed that there will only be one ship moored directly in front of his ship's assigned berth, yet as he approaches the pier area, he may visually oberve that there is now an additional floating barge directly behind the assigned berth. Therefore, as the ship enters the pier area, the conning officer must quickly assess the situation and apply it to his already planned strategy or mental picture. As the conning officer makes his visual assessment, he must also begin to slow down the ship's momemtum by decreasing its speed. The key in slowing the ship's forward motion is to allow the conning officer to be able to control the ship's motion as he positions the ship for its approach.

Goal: Safely Moor A Ship Alongside A _Pier	
(F)	Complete_Brief_Phase
(G)	Ensure_Ship_And_Crew_Ready
(H)	Enter_Pier_Area
(I)	Complete_Pier_Approach_Phase
(J)	Complete_Positioning_And_Stopping
(K)	Complete_Maneuver_Ship_Against_Pier
(L)	Complete_Doubling_Lines_Phase

Figure 15. Task Map for Mooring.

. **goal: Enter_Pier_Area (H)**

. . goal: Safely_Complete_Harbor_Transit

. . goal: Reduce_Ship's_Speed

. . . goal: Issue_Engine_Order ...to lee helmsman

. . . . goal: Determine_Engine_To_Use

. . . . . [select: Port_Engine ...to affect port screw

. . . . . Starboard_Engine ...to affect starboard screw]

. . . . goal: Determine_Direction_Of_Engine

. . . . . [select: Use_Backing_Bell ...if reversing motion is desired

. . . . . Use_Combination_On_Two_screws ...if twisting is desired]

. . . . goal: Determine_Desired_Speed

. . . . . [select: Use_1/3_Bell ...if rpm for 5 knots needed

. . . . . Use_Specific_rpms ...if less than 5 knots needed

. . . . . Stop ...all throttles closed]

. . . . goal: Give_Verbal_Order_To_Lee_Helmsman

. . . goal: Receive_Repeat_Back_Of_Order_From_Lee_Helmsman

. . . . [select: Acknowledge_Repeat_Back ...if order properly understood

. . . . . Repeat_Order ...if order not properly acknowledged]

. . . . *goal: Determine_If_Engine_Order_Was_Executed* (see Table 6)

. . . . . [select: *Observe_Sound_Of_Engines_Decelerating*

. . . . . *Observe_Sound_Of_EOT_Bells_Responding*

. . . . . *Visually_Observe_Speed_Indicator_For_Decreasing_Speed*]

. . . . goal: Receive_Execution_Of_Order_From_Lee Helmsman

. . . . . [select: Acknowledge_Report ...if properly executed

. . . . . Repeat_Order ...if not properly executed]

. . *goal: Verify_Pier_Status* (see Table 12)

. . . goal: Verify_Ship's_Intended_Pier

. . . . [select: *Visually_Observe_Painted_Markings_On_Pier*

. . . . *Visually_Observe_Pier_Handlers_Standing_By*]

. . . *goal: Assess_Environmentals_And Ship_Surroundings* (see Table 2)

. . . . goal: Check_For_Change_In_Wind

. . . . . [select: *Visually_Observe_Wind_Indicator*

. . . . . *Visually_Observe_Top_Of_Water*

. . . . . *Visually_Observe_Pennants_On_Pierside_Ships*

. . . . . *Visually_Observe_Ships_Smoke_Stacks*]

. . . . goal: Check_For_Change_In_Current

. . . . . [select: *Visually_Observe_Floating_Debris_In_Water*

. . . . . *Visually_Observe_How_Floating_Objects_Tend_In_Water*]

In addition to making an assessment of the pier surroundings, the conning officer must also confirm the berth the ship is to moor. Although very uncommon, the conning officer may have a situation in which the designated pier is not prepared to receive the ship alongside. If this were to happen, the conning officer would confer with the commanding officer and pilot as to what steps should be taken next. Usually, the ship would slow to bare steerage way and wait for the pier to become ready before continuing on with its approach to the pier. The conning officer has many visual cues that indicate whether a pier is ready to receive a ship or not.

. . . *goal: Verify_Pier_Is_Ready_To_Receive_Ship* (see Table 14)

. . . . [select: *Visually_Observe_Pier_Line_Handlers_Standing_By*

. . . . *Visually_Observe_Crane_And_Brow_Standing_By*

. . . . *Visually_Observe_Bridge_Marker*

. . . . *Visually_Observe_Family_And_Friends_Waiting*

. . . . Call_Port_Authority ...if no visual cues available]

As mentioned earlier, the strategy in which a conning officer makes an approach to the pier is dependent on the specific situation. For this particular task analysis, the ship approaches the pier head on, in which the path to the berth is unrestricted by any ships already tied to the pier. The goal of the conning officer here is to approach the pier with the bow of the ship at an angle between 10 and 20 degrees with the pier. The key behind this strategy is that with the ship approaching at a small angle it allows the conning officer to get the bow of the ship close to the pier and then swing the stern in towards the pier using a twisting motion. Similar to getting underway, a tug will tie up to the ship's port bow at this point so that it can assist in moving the bow away from the pier as the ship begins to swing its stern towards the pier.

Goal: Safely Moor A Ship Alongside A _Pier	
(F)	Complete_Brief_Phase
(G)	Ensure_Ship_And_Crew_Ready
(H)	Enter_Pier_Area
(I)	Complete_Pier_Approach_Phase
(J)	Complete_Positioning_And_Stopping
(K)	Complete_Maneuver_Ship_Against_Pier
(L)	Complete_Doubling_Lines_Phase

Figure 16. Task Mooring for Mooring.

. **goal: Complete_Pier_Approach_Phase (I)**

. . goal: Maneuver_Ship_So_It_Has_Proper_Approach_Angle_With_Pier

. . . goal: Issue_Rudder_Order ...to helmsman

. . . . goal: Determine_Direction_Of_Rudder

. . . . . [select: Use_Left_ Rudder ...to swing bow left, stern swing right

. . . . . Use_Right_Rudder ...to swing bow right, stern swing left]

. . . . goal: Determine_Amount_Of_Rudder ...Depending on situation

. . . . . [select: Desired_Degrees_Of_Rudder] ...15 degrees of rudder angle

. . . . goal: Give_Verbal_Order_To_Helm

. . . . goal: Receive_Repeat_Back_Of_Order_From_Helmsman

. . . . . [select: Acknowledge_Repeat_Back ...if order properly understood

. . . . . Repeat_Order ...if order not properly acknowledged

. . . . goal: Determine_If_Rudder_Order_Was_Executed

. . . . . method: Observe Rudder Angle Indicator

. . . . goal: Receive_Report_That_Order_Was_Executed_From_Helsman

. . . . . [select: Acknowledge_Execution ...if properly executed

. . . . . . Repeat_Order ...if not properly executed]

. . . goal: Determine_Motion_Of_Ship

. . . . [select: Observe Change In Lateral Separation Between Ship And Pier

. . . . Visually Observe Swing of Stern]

As the conning officer begins the ship's approach to the pier he positions himself on the bridgewing that will be facing the pier, which in this scenario is the starboard bridgewing. At this time, the conning officer will again assess the environmental effects and the surrounding area.

. . *goal: Assess_Environmentals_And_Ship_Surroundings* (see Table 2)

. . . goal: Position_Yourself_On_Bridgewing

. . . . [select: Port side Bridge wing ...if moored on port side

. . . . Starboard Bridge wing ...if moored on starboard side]

. . . goal: Determine_Wind_Direction_And_Speed

. . . . [select: Take reading from anonometer

. . . . *Visually observe direction wind bird is pointing*

. . . . *Visually observe direction ships flags/pennants are blowing*

. . . . *Visually observe direction of wind generated wakes on water*]

. . . goal: Determine_Current

. . . . [select: *Visually observe wake in water about pier pilings*

. . . . *Visually observe direction fenders tend in water*

. . . . *Visually observe wake in water about channel buoy*

. . . .	*Visually observe direction and rate of speed of floating objects*

. . . .	Look at tide and current charts]

. . *goal: Visually_Assess_Distance_To_Nearest_Obstructions* (seeTable 3)

. . . goal: Determine_Distance_Between_Bow_And_Closest_Obstruction

. . . . [select: *Visually judge distance*

. . . .	Receive estimated distance from bow watch

. . . .	Use distance reported by surface radar

. . . .	Confer with commanding officer, pilot, or OOD]

. . . goal: Determine_Distance_Between_Stern_And_Closest_Obstruction

. . . . [select: *Visually judge distance*

. . . .	Receive estimated distance from stern watch

. . . .	Use distance reported by surface radar

. . . .	Confer with commanding officer, pilot, or OOD]

. . . goal: Determine_Distance_Between_Beam_And_Closest_Obstruction

. . . . [select: *Visually judge distance*

. . . .	Check distance reported by radar

. . . .	Confer with commanding officer, pilot, or OOD]

. . *goal: Complete_Assessment_Of_Ship's_Movement/Position* (see Table 8)

. . . goal: Determine_Motion_Of_Ship

. . . . [select: *Visually Observe Change In Separation Between Ship And Pier*

. . . .	*Visually Observe Swing of Stern*

. . . .	*Visually Observe Swing of Bow*]

. . . goal: Monitor_Distance_Opening/Closing_Rate

. . . . [select: goal: *Visually Observe Separation Between Ship And Pier*

. . . .   . method: *Visually watch ship, at waterline, move away from pier*

. . . .   Request Distances From Bow/Stern Watches]

. . goal: Make_Adjustments   ...if necessary

Once the conning officer has maneuvered the ship into its angled approach, he must immediately reduce the momemtum of the ship so that it does not drift into the pier.

. . goal: Reduce_Ship's_Speed_To_Bare_Steerage_Way

. . . goal: Issue_Engine_Order   ...to lee helmsman

. . . . goal: Determine_Engine_To_Use

. . . . . [select: Port_Engine   ...to affect port screw

. . . . .   Starboard_Engine   ...to affect starboard screw

. . . . .   All_Engines   ...to affect both screws]

. . . . goal: Determine_Direction_Of_Engine

. . . . . [select: Use Backing Bell   ...if reversing motion is desired

. . . . .   Use_Combination_On_Two_screws   ...if twisting motion]

. . . . goal: Determine_Desired_Speed

. . . . . [select: Use_1/3_Bell   ...if rpm for 5 knots needed

. . . . .   Use_Specific_rpms   ...if less than 5 knots needed

. . . . .   Stop   ...all throttles closed]

. . . goal: Give_Verbal_Order_To_Lee_Helmsman

. . . goal: Receive_Repeat_Back_Of_Order_From_Lee_Helmsman

. . . . [select: Acknowledge_Repeat_Back   ...if order properly understood

. . . . .   Repeat_Order   ...if order not properly acknowledged]

. . . goal: *Determine_If_Engine_Order_Was_Executed* (see Table 6)

. . . . [select: *Observe sound of engines decelerating*

. . . . *Observe sound of engine bells responding*

. . . . *Visually observe speed indicator for decreasing speed*]

. . . goal: Receive_Execution_Of_Order_From_Lee Helmsman

. . . . [select: Acknowledge_Report ...if properly executed

. . . . Repeat_Order ...if not properly executed]

As the ship slowly approaches the pier, the conning officer will then order the tug to tie up just aft of the port bow. By doing this, the tug prepares to assist in swinging the ship's bow away from the pier as well as help in slowing the forward motion of the ship.

Goal: Safely Moor A Ship Alongside A _Pier	
(F)	Complete_Brief_Phase
(G)	Ensure_Ship_And_Crew_Ready
(H)	Enter_Pier_Area
(I)	Complete_Pier_Approach_Phase
(J)	Complete_Positioning_And_Stopping
(K)	Complete_Maneuver_Ship_Against_Pier
(L)	Complete_Doubling_Lines_Phase

Figure 17. Task Map for Mooring.

. goal: Complete_Positioning_and_Stopping (J)

. . goal: Order_Tug_To_Tie_Itself_Up_To_Ship's_Port_Bow

. . . [select: Verbally relay order through pilot ...if pilot wishes to control tug

. . . Verbally pass over hand held radio]

Depending on the scenario and evironmental conditions, the conning officer will generally allow the bow of the ship to approach as close as 25 – 50 feet of the pier. The purpose is to maneuver the ship as close to the pier as possible so that the mooring lines can be easily cast over to the pier. With the ship in this position, the conning officer is also able to quickly align the ship so that it is parallel with the pier by swinging its stern towards the pier. By having the ship parallel and within close proximity of the pier, the conning officer can now send over all of the mooring lines and prepare to walk the ship up against the pier.

. . goal: Approach_Within_25-50_Feet_Of_Pier ...depends on conditions

. . . *goal: Assess_Position_And_Rate_Of_Movement_Of_Bow* (see Table 8)

. . . . [select: *Observe movement of bow against fixed point on pier*

. . . . *Visually_Observe_Distance_Between_Bow_And_Stern*

. . . . Request rate of change and distance of bow from bow watch]

. . goal: Maneuver_Ship_So_Mooring_Side_Is_Parallel_To_Pier

. . . goal: Swing_Stern_Towards_Pier

. . . . method: Order rudder in direction away from pier

. . . *goal: Assess_Position_And_Rate_Of_Movement_Of_Stern* (see Table 8)

. . . . . [select: *Visually observe relative motion between stern and pier*

. . . . . . *Visually_Observe_Wake_Of_Stern*

. . . . . . Request rate of change and distance of stern from stern watch]

. . . . goal: Make_Adjustments_To_Swinging_Stern ...if necessary

. . . . . [select: Backing_Bell_On_Engines ...if loss of headway

. . . . . . Rudder_Amidships ...if slow rate of swing

. . . . . . Shift_Your_Rudder ...if fast rate of swing]

. . . goal: Verify_Ship_Is_Parallel_To_Pier_And_Maintaining_Separation

. . . . [select: *Measure_Distance_Between_Ship_And_Pier* (see Table 9)

. . . .   Query Bow/Stern Watches For Separation Distances]

. . goal: Stop_Headway_Of_Ship

. . . [select: Order_Backing_Bell_On_Outboard_screw   ...if slight headway

. . .   Order_Backing_Bell_On_Both_screws   ...if moderate headway]

. . . goal: Verify_No_Forward_Motion

. . . . *method: Assess ship's movement and position* (see Table8)

. . . goal: Order_Engine(s)_Stopped

. . goal: Send_Over_All_Lines

. . . [select: Verbally_Pass_Using_Hand_Held_Radio

. . . .   Verbally_Pass_Over_Sound_Powered_Phones]

The key for the conning officer is to ensure that the ship's position is parallel to the pier before "walking the ship" up against the pier. The conning officer will use the ship's engines and the tug to ensure the ship is aligned correctly. Generally, there is also a marker on the pier that designates where the bridge of the ship should be aligned to. The marker can be anything such as a painted letter on the pier or a parked truck with a bright orange construction cone on its hood marking the spot. Additionally, there are fenders, rubber cylinders used to protect the sides of the ship, that are secured to the pier in which the conning officer also uses as references as how to properly align the ship. The fenders are positioned specifically to accommodate the varying size and shape of each respective ship type.

As the mooring lines are sent to the pier and wrapped around the bollards or chocks, which are strong, cylindrical uprights on the pier, the conning officer must ensure that the ship maintains its close proximity and parallel position with the pier. This is accomplished by monitoring the ship's position in relation to the fixed object on the pier and making any adjustments through the use of the ship's engines or assisting tug. The conning officer will also continually scan the entire length of the ship and observe any changes in the separation between the ship and pier.

Goal: Safely Moor A Ship Alongside A _Pier	
(F)	Complete_Brief_Phase
(G)	Ensure_Ship_And_Crew_Ready
(H)	Enter_Pier_Area
(I)	Complete_Pier_Approach_Phase
(J)	Complete_Positioning_And_Stopping
(K)	Complete_Maneuver_Ship_Against_Pier
(L)	Complete_Doubling_Lines_Phase

Figure 18. Task Map for Mooring.

. **goal: Complete_Moving_In_And_Setting_Lines_Phase (K)**

. . *goal: Verify_Ship_Properly_Aligned_With_Pier* (see Table 13) ...repeated

. . . [select: *Visually_Check_Bridge_Aligned_With_Bridge_Marker_On_Pier*

. . . *Visually_Verify_Fenders _Are_In_Correct_Position*

. . . *Compare ship's heading with pier heading*

. . . goal: Ask_Pier_Supervisor_To_Confirm_Alignment

. . . . [select: Use_Hand_Held_Radio

. . . . Verbally_Yell

. . . . Use_Hand/Body_Signals]]

. . goal: Monitor_Ship's_Position_And_Distance_From_Pier ...repeated

. . . [select: *goal: Assess ship's movement and position* (see Table 8)

. . . *goal: Measure_Distance_Between_Ship_And_Pier* (see Table 9)]

. . goal: Make_Adjustments_To_Ship's_Position …repeated as necessary

. . . goal: Give_Engine_Order

. . goal: *Verify_All_Lines_Passed* (see Table 4)

. . . [select: *Visually observe mooring lines being placed around bollards*

. . . Receive reports from all Line Handling Stations]

With all of the lines secured to the pier, the conning officer will order the bow and stern lines to be taken to the capstan. The capstan is an electronic or hydraulic winch located near the bow and stern of the ship and is used to heave in on the mooring lines when extreme force is needed to take the slack out of the lines or walk the ship up against the pier. As the capstans heave in on the mooring lines the ship is drawn in towards the pier. The conning officer can also use the assisting tug boat to help push the ship up against the pier.

. . goal: Move_Ship_In_Against_Pier

. . . goal: Give_Order_To_Take_Bow_And_Stern_Lines_To_The_Capstan

. . . . [select: Verbally_Pass_Using_Hand_Held_Radio

. . . . Verbally_Pass_To_Phone_Talker]

. . . goal: Give_Order_To_Heave_Around_On_Bow/Stern_Lines

. . . . [select: Verbally_Pass_Using_Hand_Held_Radio

. . . . Verbally_Pass_To_Phone_Talker]

The conning officer continues to check the position of the ship with the pier and makes any adjustments necessary. However, if the conning officer does need to make adjustments to the position of the ship, they are usually very quick engine orders. For example, as the ship moves in against the pier, it may be necessary for the ship to move 5 feet forward or backward in order for the ship to rest properly against the fenders. Therefore, the conning officer may order a one-third bell on the engines for only a matter of seconds in order to move the ship the required five feet.

. . goal: Monitor_Ship's_Position_And_Distance_From_Pier ...repeated

. . . [select: *goal: Assess ship's movement and position* (see Table 8)

. . . *goal: Measure_Distance_Between_Ship_And_Pier* (see Table 9)]

. . goal: Make_Adjustments_To_Ship's_Position ...repeated as necessary

. . . goal: Give_Engine_Order

. . *goal: Verify_Ship_Properly_Against_Pier* (see Table 13)

. . . [select: *Visually observe contact between ship and fenders/camel*

. . . *Physically feel ship make contact with fenders/camel*]

The final phase of the mooring evolution consists of having all of the ship's mooring lines doubled up. However, before this can happen, the ship must have all of its lines singled first. Usually, a ship can maintain its position by just having the lines singled up, however, having the lines doubled up increases the overall strength of the moor.

Goal: Safely Moor A Ship Alongside A _Pier	
(F)	Complete_Brief_Phase
(G)	Ensure_Ship_And_Crew_Ready
(H)	Enter_Pier_Area
(I)	Complete_Pier_Approach_Phase
(J)	Complete_Positioning_And_Stopping
(K)	Complete_Maneuver_Ship_Against_Pier
(L)	Complete_Doubling_Lines_Phase

Figure 19. Task Map for Mooring.

. **goal: Complete_Doubling_Up_Lines_Phase (L)**

. . goal: Ensure_Ship_Maintains_Proper_Alignment_With_Pier

. . goal: Monitor_Ship's_Position_And_Distance_From_Pier

. . . goal: Make_Necessary_Adjustments_To_Maintain_Proper_Alignment

. . . . [select: goal: Give_Engine_Order

. . . . goal: Issue_Rudder_Order]

. . goal: Order_All_Lines_Singled_Up

. . . goal: Receive_Report_From_All_Line_Handling_Stations

. . . . [select: Use hand held radio

. . . . Use phone talker]

. . goal: Ensure_Mooring_Lines_Properly_Maintain_Ship's_Position

. . goal: Monitor_Ship's_Position_And_Distance_From_Pier ...same as before

. . . goal: Make_Adjustments_To_Ship's_Position ...if necessary

. . . . [select: Give order to take slack out of affected lines

. . . . Give order to take affected lines "to power"]

. . goal: Ensure_All_Lines_Singled_Up

. . . goal: Receive_Report_From_All_Line_Handling_Stations

. . . . [select: Use hand held radio

. . . . Use phone talker]

. . goal: Issue_Order_To_Double_Up_All_Lines

. . . [select: Use_Hand_Held_Radio

. . . Use_Phone_Talker]

. . goal: Ensure_All_Lines_Doubled_Up

. . . goal: Receive_Report_From_All_Line_Handling_Stations

. . . . [select: Use hand held radio

. . . . Use phone talker]

Once all of the mooring lines are successfully doubled up, the conning officer is finished with the mooring evolution.

C. CRITICAL CUE INVENTORIES

The secondary goal of this thesis was to provide an inventory of all of the perceptual cues utilized by the conning officer while he or she was conducting pier side evolutions. As shown in the previous GOMS-like model for getting a ship underway from a pier or moored to a pier, a conning officer's ability to make quick effective decisions greatly relies on his capacity to analyze and process the perceptual cues around him. Critical cues used by experienced ship drivers during pier side evolutions were identified using a Critical Decision Method (CDM) knowledge elicitation process. A Critical Cue Inventory (CCI), which lists the critical cues used and a description of each cue, was developed for the phases of each evolution. The cue descriptions detail what the conning officer was seeing or hearing at the time he made his decision as well as why this particular cue was chosen for the specific phase of the task.

The CCIs were constructed by using a table format with the perceptual cues listed on the left hand side and their descriptions on the right hand side of the table. The title of each table indicates the phase or subgoal where these cues were applied or used.

Critical Cue Inventory for	
Phase: A, I	**Subgoal:** Assess_Environmentals_And_Ship_Surroundings
CUE	**DESCRIPTION**
State of water in channel	Used by the conning officer to estimate the direction and magnitude of the wind. The conning officer is looking at the white caps or ripples in the water created by the wind. He will also determine the direction of the wind by the flow of the white caps or ripples. Calm water indicates the absence of a strong wind.
Pennants/Flags	Used for estimating wind direction and magnitude. The direction the flag or pennant blows indicates the direction of the true wind. The magnitude of the wind can be determined by looking at the flag as well as the sound the flag makes as it flaps. Quick, succinct whipping noises usually indicate a strong wind.
Buoys	Used to assess wind and current. The way the buoy tends is a indication of the direction of the wind or current. Normally, a buoy floats upright, however, a strong wind or current will cause it to lean to one side or the other. Another indication is the wake it generates. The direction of the wind can be determined by the direction the wake flows.
Fenders	Used to assess wind and current. The fenders are used to protect the ship from physically rubbing up against the pier (see fig.2). If the fenders freely float between the ship and pier it is an indication that the ship is being "set off" of the pier. A fender that is being extremely pinched gives the indication that the ship is being "set on" against the pier.
Mooring Lines	Used to assess wind or current. The lines that secure the ship to the pier give indications by the tension that is exerted on them. Very taught lines indicate the ship is being set off of the pier. Very loose or slack lines indicate the ship is being set on to the pier.
Wind bird	Used to measure direction and magnitude of wind. Located high up on the ship's mast, the wind bird provides the conning officer a visual reference to the wind. The direction it points to represents the direction from which the wind is blowing. The rate at which its small propeller spins indicates the magnitude of the wind.

Table 2. Critical Cue Inventory for Assessing Environmentals.

Critical Cue Inventory for	
Phase: B, I	**Subgoal:** Assessing_Ship's_Distance_To_Nearest_Obstructions
CUE	**DESCRIPTION**
Separation between bow and pier	Used to provide reference point for the conning officer for space between the ship's bow and the pier. The conning officer estimates this distance and then mentally refers back to this image so that he can determine whether the space is getting larger or smaller. What the conning officer sees is the open space or water between the edge of the ship and the pier. As this space gets larger or smaller the conning officer visually estimates the increasing or decreasing distance or separation between the ship and pier.
Separation between stern and pier	Used to provide reference point to the conning officer for space between the ship's stern and the pier. Conning officer uses this cue in the same manner as used to determine separation between bow and pier.
Distance to surrounding obstructions	Used to provide conning officer with initial mental image of ship's position in relation to the obstructions. The conning officer looks at the space between the ship and the particular object and estimates this distance. The distance between any two fixed points on the ship and object defines the space. As the space changes in size, the conning officer is able to estimate the new distance and update his mental picture of the ship's position.

Table 3. Critical Cue Inventory for assessing distance between ship and pier.

Critical Cue Inventory for	
Phase: C	**Subgoal:** Complete_Single_Up_All_Lines_Phase
CUE	**DESCRIPTION**
State of mooring lines	Initial assessment of mooring lines was conducted when lines were doubled so conning officer looks to see if tension in mooring lines change once lines singled. Again, conning officer is looking to see if lines are dramatically taught or slack, which would indicated whether the ship is being set off or set on the pier, respectively.
Casting off of mooring lines	Used by conning officer to determine when the ship is officially underway, which happens when all of the lines have been physically removed from the pier. The conning officer watches the pier line handlers physically remove the end of the line from the pier and toss it into the water where it is eventually pulled in by the ship's line handlers.

Table 4. Critical Cue Inventory for single up lines phase.

Critical Cue Inventory	
Phase: C	**Subgoal:** Visually_Check_State_Of_Mooring_Lines
CUE	**DESCRIPTION**
Heavy strain on mooring line	Used to indicate that external force, such as winds or currents, is causing ship to be set off of the pier. The conning officer will visually look to see if the line has become very taught. If the strain is very extreme, the mooring line will also begin to make cracking sounds.
Slack in the mooring line	Used to indicate that external force, such as winds or currents, is causing ship to be set on to the pier. The conning officer will visually look to see if the line begins to dip down towards the water creating an inverted arch.

Table 5. Critical Cue Inventory for checking state of mooring lines.

Critical Cue Inventory for	
Phase: C, H	**Subgoal:** Determine_If_Engine_Order_Was_Executed
CUE	**DESCRIPTION**
Churning of water at stern of ship	As an engine order is executed, the conning officer can visually look aft by the stern and see an affect as the propellers begin to turn. The conning officer will notice a smoothing out of the water as millions of tiny bubbles created by the rotating of the propeller rise to the surface.
Plume of smoke exiting smoke stack	Used to visually determine if engine order was executed. The conning officer will look to see if the additional smoke escapes the smokestack.
Sound of engines accelerating	Used to audibly determine if engine order was executed. As the ship's engines increase or decrease in speed it makes a distinctive revving sound. Standing on the bridge wing, generally provides the conning officer the best opportunity to hear the engine changing speeds.
Hear bell of EOT acknowledgment	Used to audibly determine if engine order was executed. The ringing of the Engine Order Telegraph (EOT) signals to the conning officer that the engineering plant has acknowledged the engine order and are executing the order.

Table 6. Critical Cue Inventory for determining engine order executions.

CRITICAL CUE INVENTORY FOR	
Phase: C, D	**Subgoal:** Assess_Response_Of_Ship
CUE	***DESCRIPTION***
Change in Separation between Ship and Pier	Used to determine the motion of the ship. The conning officer will visually watch the space between the edge of ship and the edge of the pier. As the space gets larger it indicates that the ship is moving away from the pier. As the space decreases in size, the indication is that the ship is moving towards the pier.
Rate of swing of the ship's bow or stern	Used to determine the rate at which the ship is moving in relation to the pier or fixed object. The conning officer wants a rate of swing that is fast enough to quickly get away from the pier, but not so fast as to be unable to control the momentum of the moving ship. For the bow, the conning officer will look at the "bull nose", an opening at the tip of the bow used to pass the forward mooring line through, and observe the rate at which the water or fixed objects pass by. The conning officer observes the swing of the stern by looking at the corner of the stern and watching it move through the water.

Table 7. Critical Cue Inventory for assessing response of ship.

Critical Cue Inventory for	
Phase: C, J	**Subgoal:** Assessment_Of_Ship's_Movement_And_Position
CUE	**DESCRIPTION**
Change in separation between ship and pier	Used to determine motion of the ship. The conning officer will visually watch the space between the edge of the ship and the edge of the pier. As the space gets larger it indicates that the ship is moving away from the pier. As the space decreases in size, the indication is that the ship is moving towards the pier.
Rate of swing of the ship's bow and stern	Used to determine the rate at which the ship is moving in relation to the pier or a fixed object. The conning officer wants a rate of swing that is fast enough to efficiently move away from the pier, but not so fast as to be unable to control the momentum of the moving ship. For the bow, the conning officer can look through the "bull nose," an opening at the tip of the bow used to pass the forward mooring line through, or look at the jack staff and observe the rate at which the water or fixed objects in the distance pass by. The conning officer observes the swing of the stern by looking at the corner of the stern and watches the rate at which it moves through the water.
Forward or aft motion of a fixed point on the pier	Used to determine the forward or aft motion of the ship. The conning officer will select a fixed point on the pier, such as crate or paint marking, and will watch to see if it develops some sort of relative motion. For example, if the conning officer chooses an empty box on the pier and it appears to drift forward, then the conning knows the ship is moving backward or aft. If the box appears to drift backward, then the conning officer knows the ship is moving forward or has gained some headway.

Table 8. Critical Cue Inventory for assessing the ship's motion and position.

Critical Cue Inventory for	
Phase: C, D, E, J	**Subgoal:** Measure_Distance_Between_Ship_And_Pier
CUE	**DESCRIPTION**
Open space between ship's stern and pier	Used to determine distance between stern of ship and pier. The conning officer will get an estimated initial distance between stern and pier by looking at the space between the edge of the stern and the side of the pier. Usually, the conning officer will compare the distance of the space with a known visual reference, such as the ship's brow, which is the metal walkway used by personnel to embark and disembark the ship. For example, if the brow is currently in place and is approximately 16 feet in length, the conning officer can then determine an initial distance for the open space before the ship begins to move is around 16 feet.
Open space between ship's bow and pier	Used to determine the distance between the bow of the ship and the pier. This distance is determined in the same manner as it is for estimating the distance between the stern and pier. However, since most navy ships have bows that curve away from the pier, the conning officer will have to compensate his estimate by adding extra feet to the estimated distance of the open space.
Open space between ship's amidships, or middle, and pier	Used to determine the distance between the amidships of the ship and the pier. Method is the same as for the stern and bow, however, the conning officer will observe the space between the side of the ship at its amidships and the pier.
Diameter of fenders	Used to determine the distance between ship and pier. The conning officer can look down at the water's edge and judge the distance between the ship and pier by visually looking at the fender. Although different fenders vary in size, the conning officer can get a good distance estimate by looking at the size of the fender as it sits between the ship and pier.

Table 9. Critical Cue Inventory for measuring distance between ship and the pier.

Critical Cue Inventory for	
Phase: D	**Subgoal:** Monitor_Intended_Course_For_Surface_Contacts
CUE	**DESCRIPTION**
Scan horizon for any other surface contacts	Used to determine if intended course is safe to use. The conning officer will continually look out into the harbor channel for any other ships or small craft that may cause the ship to deviate from its planned course out of the pier area. This is important to the conning officer because there is very little room to maneuver the ship once it begins to clear the pier. Generally, other traffic that is already underway will be allowed to clear before commencing out into the channel.

Table 10. Critical Cue Inventory for monitoring for other surface contacts.

Critical Cue Inventory for	
Phase: E	**Subgoal:** Determine_When_To_Commence_Turn
CUE	**DESCRIPTION**
Change of water state at end of pier	Used to determine when to commence turn. The conning officer looks at the water in the vicinity of the end of the pier for an indication that there may be a change in the current. Any change in the current can effect the rate at which the ship can execute its turn.
Indications of strong wind	The conning officer in determining when to commence the turn can also use the same techniques used in assessing the environmentals acting on the ship. The presence of a strong wind, 15 – 30 knots, can effect the turn capabilities of the ship in two ways. If the ship turns into the wind it can slow the rate of turn. Thus, the conning officer must compensate for this and commence the turn earlier than normal. If the ship turns with the wind, the rate of turn can be increased forcing the conning officer to turn later than normal.

Table 11. Critical Cue Inventory for determining when to commence a turn.

Critical Cue Inventory for	
Phase: H	**Subgoal:** Verify_Pier_Status_Agrees_With_What_Was_Briefed
CUE	**DESCRIPTION**
Painted markings on pier	Used to confirm designated berth for ship. The conning officer will visually scan the intended pier for any painted markings that designate the its specific location. For example, a pier may have "B 17" painted on its side, which indicates its specific designation.
Pier line handlers standing by to assist	Used to confirm designated berth for ship. As the ship approaches the designated pier, the conning officer will look to see if there are personnel standing by to assist in mooring the ship to the pier. Without these personnel on the pier, the ship cannot continue with the evolution and must wait until they arrive.
Family members on pier	Used to confirm designated berth for ship. At the end of a long underway period, often times there will be family members waiting on the pier for the ship to return. The conning officer will also see signs that welcome back the ship and its crew.

Table 12. Critical Cue Inventory for verifying ship's designated berth.

Critical Cue Inventory for	
Phase: K	**Subgoal:** Verify_Ship_Properly_Aligned_With_Pier
CUE	**DESCRIPTION**
Bridge wing is aligned with marker on pier	Used to verify the proper alignment of the ship with the pier. The conning officer will visually align his position on the bridge wing of the ship with the marker on the pier. If for some reason the conning officer needs to make minor adjustments to the ship's position he uses the marker on the pier as the reference point on how far he must move the ship.
Fenders between ship and pier	Used to verify the proper alignment of the ship with the pier. The conning officer will visually look down at the fenders to see if they are touching both the ship and the pier. If they are floating freely, then the ship is not all the way against the pier or the fender is not properly placed. If the fenders visually look like they are being pinched between the ship and pier then the ship is properly against the pier.

Table 13. Critical Cue Inventory for verifying ship's alignment with pier.

Critical Cue Inventory for	
Phase: H	**Subgoal:** Verify_Pier_Is_Ready_To_Receive_Ship
CUE	**DESCRIPTION**
Pier line handlers standing by to assist	Used to confirm pier is ready to receive ship. As the ship approaches the designated pier, the conning officer will look to see if there are personnel standing by to assist in mooring the ship to the pier. Without these personnel on the pier, the ship cannot continue with the evolution and must wait until they arrive.
Crane and brow on pier	Used to confirm pier is ready to receive ship. The conning officer will visually scan pier for the presence of a crane and brow. The crane is used to hoist the brow up to the ship so personnel can embark or disembark the ship. Although a ship can still moor to the pier without the crane or brow, the sight of them indicates the pier is ready to receive the ship.
Bridge marker	Used to confirm pier is ready to receive ship. The conning officer will visually scan the pier to see if there is something marking the spot at which the bridge of the ship must align with. The marker can be either an orange pylon, a painted letter on the pier, the pier supervisor standing waving his hands, or a parked truck.

Table 14. Critical Cue Inventory for verifying pier is ready to receive ship.

Critical Cue Inventory for	
Phase: A	**Subgoal:** Verify_Engines_Are_Started_And_Online
CUE	***DESCRIPTION***
Look at status board on bridge	Used to verify engines have been started. The conning officer will visually look at the status board on the bridge to confirm whether the engines are started. This board, constantly updated by an enlisted watch stander who receives reports from all over the ship via sound powered phones, displays the status of all critical components onboard the ship including the engines that are online and the steering units energized.
Hear engines start up	Used to verify engines have been started. The conning officer will often hear the whine of the engines as well as the sound of exiting smoke and steam from the smoke stacks.
See smoke come out of smoke stack	Used to verify engines have been started. The conning officer will visually look for increased flow of smoke out of the smokestack. Although there may be some smoke exiting due to other components being operated, such as the ship's Service Generators, as an engine is brought online, or started, there is a dramatic increase in the amount of smoke billowing from the smokestack.

Table 15. Critical Cue Inventory for verifying engines have started.

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VI. CONCLUSIONS

A. DISCUSSION

The impetus of this thesis was the fact that surface warfare officers have been forced to report to their first command without receiving adequate ship-handling skills even though their primary job is to be able to competently drive navy ships. The thesis also advocates that one must learn both the art and science of ship-handling in order to become a proficient ship-handler. Traditionally, the Surface Warfare Officers School (SWOS) has provided the basic theory, or science, of ship-handling to young SWOs. Unfortunately, past shortfalls in funding and equipment has prevented SWOS from adequately teaching the art of ship-handling. However, with the development of high fidelity, real time, virtual environment (VE) ship-handling simulators, young SWOs will soon have the opportunity to begin to acquire some of the prerequisite knowledge and experience needed to learn the art of ship-handling. The simulator that is being developed and tested by researchers at NAWCTSD currently has the ability to conduct an Underway Replenishment (UNREP) evolution between two ships as well as replicate simple pier work and amphibious ship-handling situations. However, this simulator, which acts as the testbed for the implementation of the Conning Officer Virtual Environment (COVE) system, must also satisfy the primary requirement of the Surface Warfare Officers School (SWOS) which is to train surface warfare officers in ship-handling for every type of ship-handling scenario. Therefore, NAWCTSD has expressed a need for comprehensive task analyses to be conducted for additional ship-handling scenarios. Hence, this thesis has been able to identify the general procedures and methodologies used by a conning officer during pier side ship-handling evolutions. In addition, the thesis provides inventories of the perceptual cues used exclusively by the conning officer while getting a ship underway or mooring it to a pier.

Initially, the intention of the thesis was to model every possible scenario that a conning officer could encounter while conducting pier side evolutions. However, it was soon discovered that it would be impossible for this thesis to efficiently delineate all of the tasks needed to accomplish the endless number of situations. Therefore, the resulting GOMS-like representations of the tasks used by a conning officer to get a ship safely underway from a pier and moored safely to a pier successfully represent the simple, generic scenario and in no way depicts every possible method that could have been utilized. In addition, another successful aspect of this thesis is that the task analysis can be reviewed by both expert and inexperienced ship-handlers. The model and its amplifying narratives and supporting cue inventories provide the reader with general and explicit decription of pier side evolutions.

The remainder of this chapter will review the thesis questions stated at the beginning and examine how each was addressed. It will also examine possible topics for future work in this subject matter. Finally, the chapter will conclude with a brief description on how this thesis can be used.

B. THESIS QUESTIONS

The following questions were addressed in this thesis:

- *What specific tasks are required of a conning officer while getting a ship underway from a pier?*

After a thorough review of ship-handling literature and training documents, the construction of a GOMS-like representation helped identify the specific tasks required of a conning officer while getting a ship underway from a pier. This method, with its very flexible and easy to follow notation, was successful in presenting a simple sequence of the general tasks used by the conning officer. This question was addressed in Chapter V.

- *What specific tasks are required of a conning officer while mooring a ship to a pier?*

Similar to how the "getting underway from a pier" model was constructed, this GOMS-like representation was also successful in identifying the required tasks used by a conning officer to moor the ship safely to a pier. This question was also addressed in Chapter V.

- *What are the perceptual cues used during pier side ship handling?*

The perceptual cues used by the conning officer during both evolutions were initially identified during the first phase of the GOMS model. The cues specified, however, only represented one viewpoint of what these perceptual cues were. Through the validation process, the thesis was very successful in eliciting a wide range of perceptual cues used during each phase of the tasks. This question was addressed in Chapter V.

- *Is the GOMS representation suitable for incorporating the perceptual cues?*

As the task analysis evolved, it was evident that the GOMS representation for each respective task, although successful in identifying the methodologies and procedures of the conning officer, was unsuccessful in properly incorporating the perceptual cues into the model. The problem was not that the model was unable to identify the perceptual cues but rather that it could not, by itself, efficiently describe why the conning officer was using these cues and what he or she was actually observing. Therefore, the thesis demonstrated that GOMS, alone, was not suitable for incorporating perceptual cues. However, by codifying the critical cue inventories developed during the CDM knowledge elicitation process with the GOMS representation, the thesis successfully addressed how perceptual cues were used and why the conning officer during pier side evolutions used them. This question was addressed in Chapters IV and V.

C. RECOMMENDATIONS FOR FUTURE WORK

The development of the COVE system is an ongoing process. Therefore, the following topics have been provided as possible areas for future work in support of the development of virtual environment ship-handling simulators.

1. Development of Additional Ship-handling Scenarios

There are many situations or scenarios that a surface warfare officer encounters when performing the duties of a conning officer. Thus, in order for future VE ship-handling simulators to be successful as training tools, they will need to be able to replicate the same events that take place in real life. The following is a list of ship-handling evolutions that would be beneficial to the continuing development of ship-handling simulators like the COVE system:

- *Harbor transiting and navigation*: This scenario should include the variability of the environmental conditions. For example, the conning officer should be able to experience different situations such as low visibility, strong external forces (currents and winds), traffic congestion, and various channels to navigate.

- *Plane guard duties*: This scenario consists of escort ships being stationed directly astern of aircraft carriers at a range of 1000 to 2000 yards for extended periods of time. This scenario should expose the conning officer to the challenge of maintaining station at high speeds and being able to safely maneuver as the aircraft carrier constantly makes changes to its course and speed. Additionally, the scenario should address the differences between day and night time plane guard operations.
- *Vessel Boarding, Search, and Seizure (VBSS) Evolutions:* This scenario consists of the conning officer maneuvering the ship within close proximity of suspected violating vessels. The scenario should expose the conning officer to conducting evasive maneuvering techniques during both day and night conditions.
- *Combat situation maneuvering:* This scenario should entail different maneuvering techniques used during combat situations, such as torpedo evasion, attacks from small water craft, and incoming missile maneuvers.
- *Man overboard maneuvering:* This scenario should provide the conning officer opportunities to train in conducting the different maneuvering techniques like the Williamson and Anderson turns.
- *Casualty control procedures:* Rarely do conning officers get the chance to practice casualty response maneuvers during critical evolutions, such as UNREPs or pier side ship-handling. Therefore, development of casualty

situations during various scenarios would offer conning officers the opportunity to practice casualty response maneuvers in a controlled environment.

2. Implement Task Analysis Using Modeling Tool

Initially, the GOMS representation created for this thesis was to have been implemented by using any one of the modeling tools available, such as using SOAR or COGNET. However, due to time constraints this idea was not fulfilled. Therefore, it may be beneficial to continue on with this thesis' work by trying to implement it with a modeling tool.

D. HOW TO USE THE TASK ANALYSIS

This task analysis should be used to assist in the further development of the VE ship-handing simulator test bed and COVE system by providing the researchers with the knowledge elicited from experienced ship-handlers. The thesis can also be used as a guide on how to efficiently map critical cue inventories to a GOMS-like representational model. Additionally, it should act as an example of how shortfalls of the GOMS-like model can be overcome by using supplemental task analysis methods.

APPENDIX A: STANDARD COMMANDS

The following is a list of standard engine and rudder commands and their definitions given by a conning officer to the Helmsman and Lee Helmsman:

Steering Commands

"Right (left) standard rudder." - Standard rudder amount required turning the ship on its tactical diameter.

"Right (left) full rudder." - Full rudder amount required for the reduced tactical diameter.

"Right (left) ___ degrees rudder." - Used to identify specific amount of rudder angle desired for turn.

"Increase your rudder to ___ degrees." - Increases the rudder angle to cause the ship to turn more rapidly.

"Ease your rudder to ___ degrees." - Decrease the rudder angle to slow ships turn.

"Rudder amidships." - Put the rudder angle at zero degrees (centerline it).

"Meet her." - Puts the rudder at the opposite angle to stop the swing of the ship.

"Steady" or **"Steady as you go."** - Helmsman adjusts rudder to steer course and maintain ships heading at the instant an order is given.

"Shift your rudder!" - Moves the rudder to the same angle but in the opposite direction.

Engine Orders

Given in three parts: 1) Engine(s) to be used, 2) Direction, and 3) Speed of engine(s)

Example: **"Starboard (port) engine ahead, one-third"**

AHEAD ONE-THIRD – rpm for 5 knots

AHEAD TWO-THIRDS – rpm for 10 knots

AHEAD STANDARD – rpm for 15 knots

AHEAD FULL – rpm for 20 knots

AHEAD FLANK – rpm for 25 knots and above

BACK ONE-THIRD – rpm astern for 5 knots

BACK TWO-THIRDS – rpm astern for 10 knots

BACK FULL EMERGENCY – backing throttle open completely

STOP – all throttles closed

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APPENDIX B: VALIDATION DOCUMENTS

A. PARTICIPANT CONSENT FORM

E. SHIP-HANDLING BACKGROUND QUESTIONNARE

C. VALIDATION WORKSHEET

CONSENT FORM
Validation for A Task Analysis of Pier Side Ship-Handling

You have been asked to participate in the validation of a task analysis of pier side ship-handling evolutions. With data from you and other participants I hope to validate my cognitive task model so that it may be used in the further development of the Conning Officer Virtual Environment (COVE) Simulator. I ask that you read and sign this form indicating that you agree to be a member of this validation process. Please ask any questions you may have before signing this document.

Background Information: This task analysis validation is being conducted for the purpose of ensuring that the cognitive model is accurate and to solicit additional perceptual cues that may have been left out.

LT Charles Grassi, USN (grassi@cs.nps.navy.mil)

Risks and benefits of being in the study: This study has no unordinary risks beyond those encountered in your everyday workplace. The benefit to participants is that the helpful insight they provide will eventually lead to a robust VE training tool that they may use in the future.

Compensation: No tangible rewards will be given. If requested, a copy of the results can be made available to you at the conclusion of the validation process.

Voluntary nature of the study: If you decide to participate, you are free to withdraw at any time without prejudice.

Questionnaire: You will be asked to fill out a ship handling background questionnaire. The purpose of this questionnaire is NOT to evaluate you in any way, but to be used solely as a means of characterizing the experience level of each participant.

Statement of consent: I have read the above information. I have asked questions and have had my questions answered. I consent to participate in the validation process.

If requested, a copy of this form can be provided for your records.

____

Signature Date email

____

Signature of Administrator Date

Ship-handling Background Questionnaire

1. Which category best represents the number of years you have served in the Navy?

   Less than 1   2-3   4-9   10-14   15 or more

2. Of that time which category best represents your time on sea duty?

   None   Under 1 Yr.   1-3 Yrs.   4-9 Yrs.   10 or more

3. Before becoming a commissioned officer, did you receive any ship-handling Experience?

   YES   NO

If you circled yes, please give the type of ship and an approximate length of time onboard:

4. On which class of ship have you spent most of your time underway?

5. How many different Commanding Officers have you worked for a while on sea duty?

6. During your career, approximately how many Mooring evolutions have you performed?

   None   1-3   4-8   9-10   1 0-15   More than 15

7. During your career, approximately how many Harbor Transits have you performed?

   None   1-3   4-8   9-10   1 0-15   More than 15

8. During your career, approximately how many UNREP approaches have you performed?

   None   1-3   4-8   9-10   1 0-15   More than 15

9. If presented with a self-operated ship-handling simulator, which of the following categories would best represent your purpose for use?

   A. Learning Basic Skills
   B. Refreshing Experience
   C. Improving Skill
   D. A Combination of the Above

10. Has this questionnaire prompted any other comments? Please feel free to use the space below to include them. Your comments and participation in this questionnaire are greatly appreciated!

THESIS VALIDATION WORKSHEET

Participant:____________________

<u>Phase:</u> <u>Cues:</u>

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